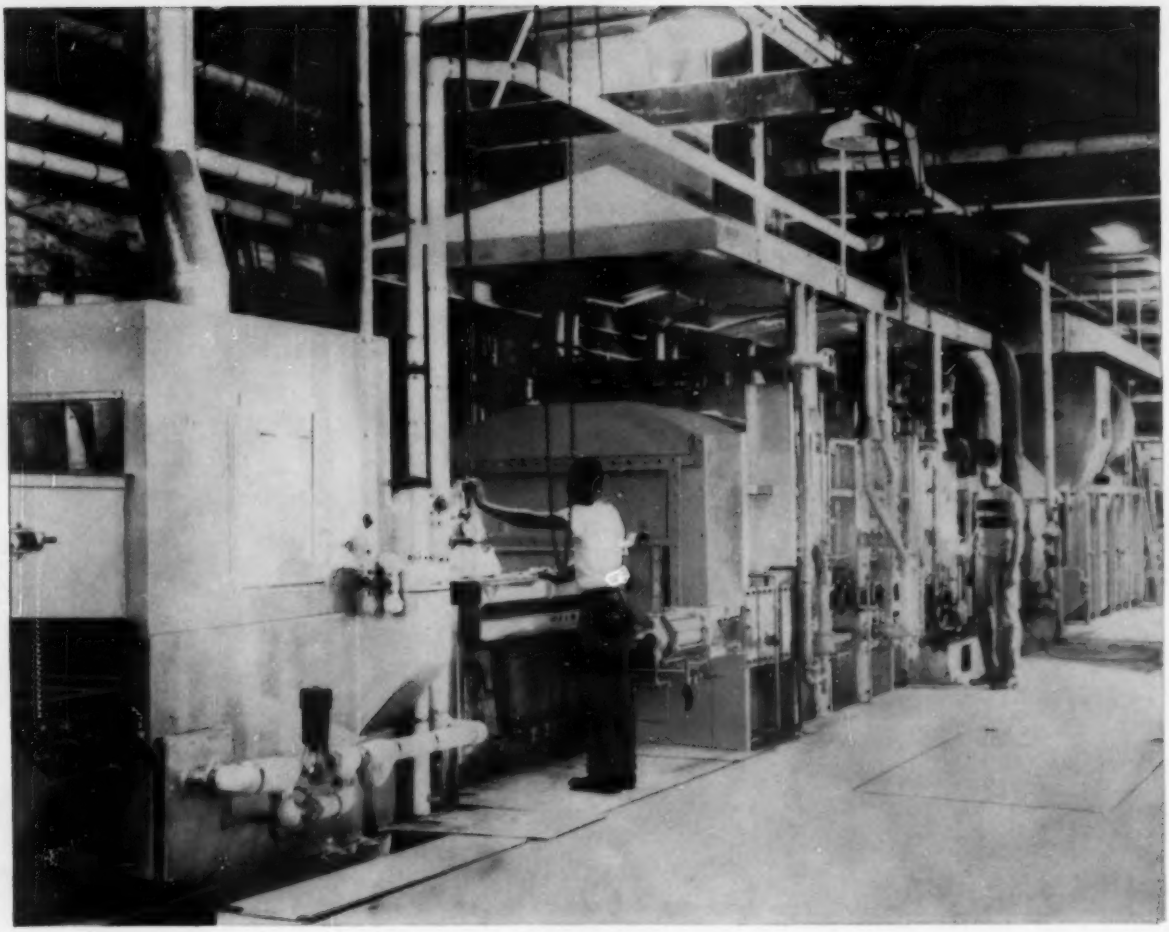
METAL *progress*



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HEAT TREATING EQUIPMENT

Metal Progress

Volume 71, No. 3

March . . . 1957

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Consulting Editors

Cover by JOHN GREEN

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The Need for Less Sulphur in Deoxidized Steel, by H. W. McQuaid and Norman P. Goss 65

Since more than 0.020% sulphur in aluminum-killed, fine-grained steel produces undesirable ferrite in supposedly all-martensitic microstructures, the authors recommend that American quality steel manufacturers install special equipment for rapid desulphurization, as is already being done in several European steelworks. (D11n, ST, S, *Al*, Ad-p35, 9-19)*

Research Management, by Arthur R. Lytle 72

An informal address (somewhat condensed) before the meeting of the Atomic Energy Commission's Welding Committee in Oak Ridge last September, wherein the speaker outlined the responsibilities and relationships between corporation executives, laboratory managers, and specialized personnel necessary to achieve commercial results from organized research. (A9g)

Movement of Dislocations, by John J. Gilman and William G. Johnston 76

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Cracking Tendency in Heavy High-Temperature Steam Piping, by Henry M. Soldan and Charles R. Mayne 78

Stabilized 18-8 (Type 347) is the conventional material for high-temperature steam service. Occasional cracks alongside welds may be avoided by using metal and welding electrodes (like 16-8-2 Cr-Ni-Mo) which have 60% reduction of area or more when cooled from 2400° F. and tested at 2300° F. (Q23p, 2-12; SS, 7-1, 9-22)

Brittle Fracture of Sheet Piling, by W. A. Morgan and R. C. A. Thurston 86

Sheet piling is usually rolled of structural steel which can meet moderate requirements. While service records are good, several failures in Canadian waters indicate that its transition temperature, where fatigue cracks or corrosion pits lead to catastrophic brittle fracture, is well above the water temperature. (Q26s, T26; AY, CN)

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METAL PROGRESS is published monthly by the AMERICAN SOCIETY FOR METALS. Publication office, Mt. Morris, Ill. Editorial, executive and advertising offices, 7301 Euclid Ave., Cleveland 3, Ohio. Subscription $7.50 a year in U.S. and Canada; foreign $10.50. Single copies $1.50; special issues $3.00 . . . The A.S.M. is not responsible for statements or opinions in this publication.

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READERSHIP RESEARCH

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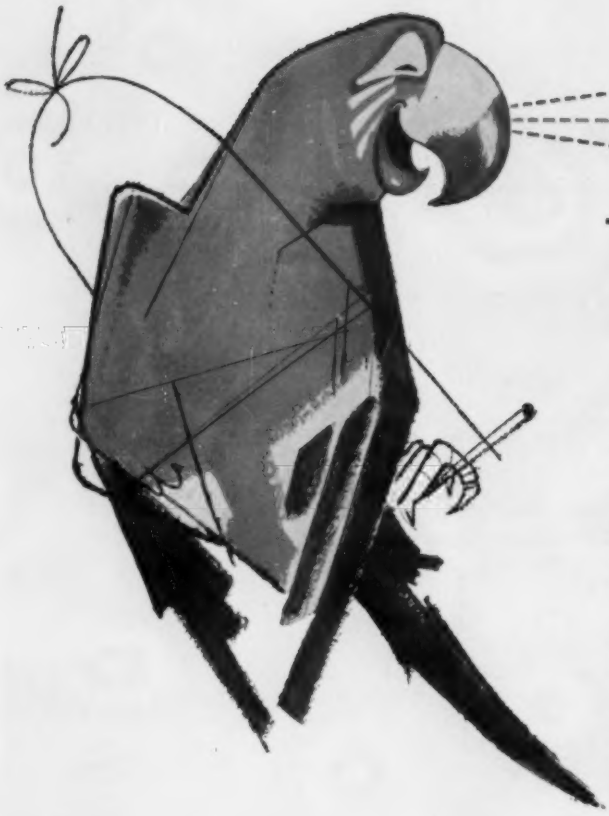

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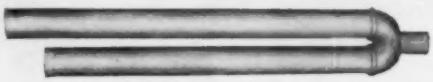

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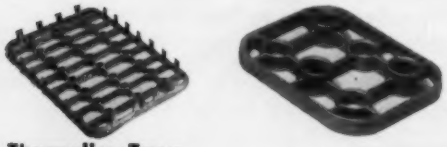

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As I was saying...

My good friend of many years, Adolph Buehler, president of the company bearing his name, wrote me a letter a couple of weeks ago. Adolph had just finished reading the complete text of my proposal for "The ASM of Tomorrow" and wrote that he "could not help but pour out deep-felt congratulations for this courageous and most splendid idea".

It was indeed a most sincere and pleasing letter and one that could not help but bring to me a rewarding and satisfying message. And Adolph was not finished when he had so eloquently described his innermost feelings for he expressed the laudable desire to contribute toward this program if it would be acceptable to the Society.

I was greatly moved by Adolph's wholehearted approval and wishes, and tried to express my deep appreciation and thanks for his commendations. I informed Adolph that the A.S.M. is a tax-exempt society and is listed on page 17 of the U. S. Treasury Department's Cumulative List of organizations to which contributions are deductible by donors from the Federal income tax. The A.S.M. has always had this status and even membership dues are deductible on personal income tax reports.

Every story should have a happy ending and my correspondence with Adolph was no exception because on New Year's Day I had the following note from Buehler Ltd. of Evanston, Ill.

"Dear Bill: Re—THE ASM OF TOMORROW

"Reference is made to our correspondence regarding the above-mentioned program. It now gives me great pleasure to enclose my check for $2,000.00 as a contribution for this noble plan of yours, 'The ASM of Tomorrow'.

"With all my best wishes, I remain

Cordially yours,

ADOLPH"

My hat is off to you, Adolph, for your generous contribution to the A.S.M. I am sure the Board of Trustees and the entire membership join with me in expressing sincere appreciation. You are the first member to make a financial contribution to further the work of the Society and I am confident your example will point out to others how the work of A.S.M. may be advanced and the dawn of "The ASM of Tomorrow" become a bright reality in the not too distant future.

We at headquarters are all inspired to great efforts.

Cordially yours,

Bill

W. H. EISENMAN, *Secretary*
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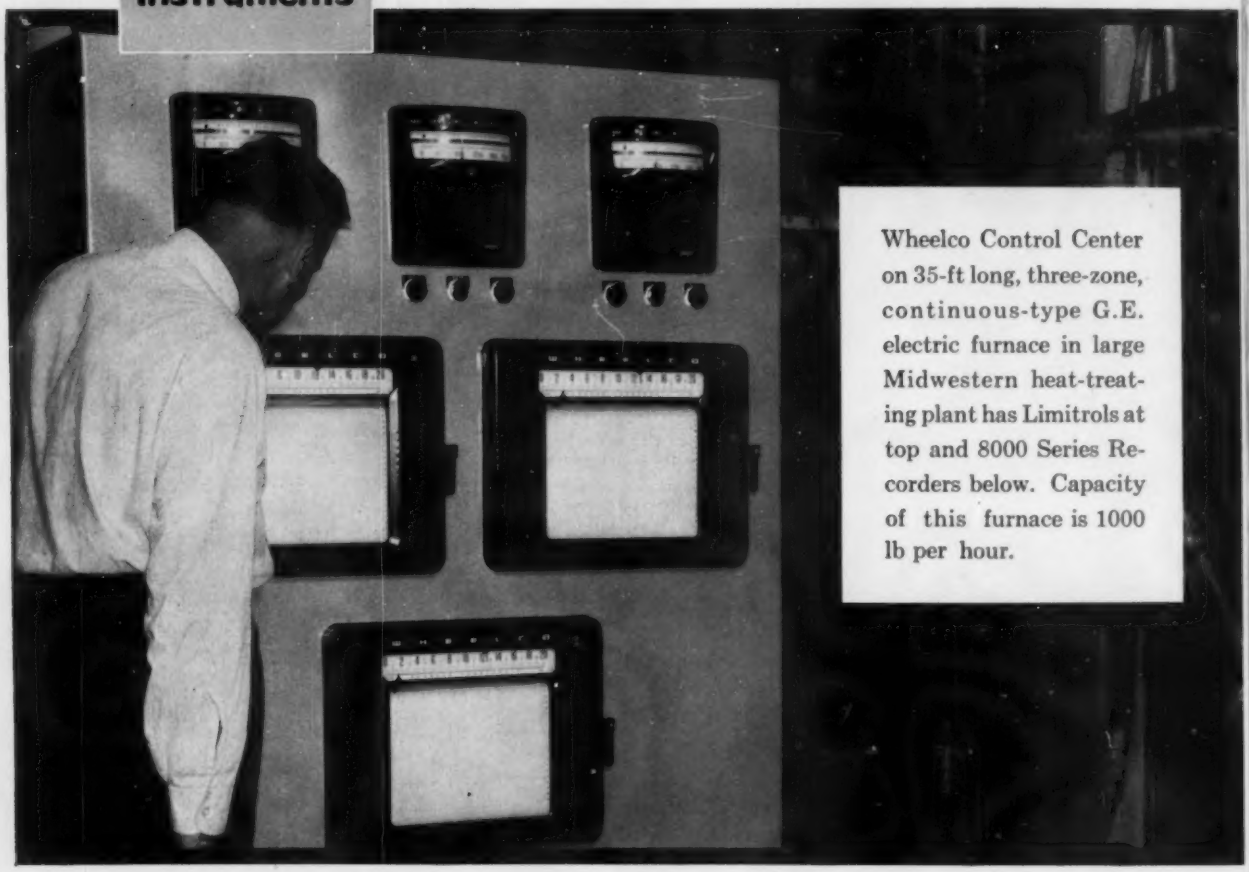

Wheelco Control Center on 35-ft long, three-zone, continuous-type G.E. electric furnace in large Midwestern heat-treating plant has Limitrols at top and 8000 Series Recorders below. Capacity of this furnace is 1000 lb per hour.

Forging, salt-bath, carbonitriding, and melting applications all improve their efficiency with Wheelco advanced design

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You'll find Wheelco Instruments installed as original equipment by leading furnace-builders and preferred by metalworking companies everywhere. Wheelco features, such as plug-in assemblies, use of standard electronic tubes, simple adjustment and scale change, mean less problems for users and are solid reasons for continued preference.

Better Die-Casting Quality . . .

Accuracy of the Wheelco Series 400 Capacitrols that control melting and holding burners improves both production and quality of aluminum die-castings. Aluminum is melted in one furnace chamber and held at precise pouring temperature of 1450° F in the other.

Precise Control for Carbonitriding . . .

Accurate temperature control, insured by use of Wheelco 8000 Series Potentiometer-Recorder, cuts costs and does away with operating problems. Recorder actuates a Barber-Colman Class 2 HYCC power unit that operates a combination air-gas valve. Capacity of radiant-tube furnace is 500 lb per hour. Wheelco Panelmount Limitrol is at top of panel.

Improved Forgings, Lower Fuel Costs...

Three big benefits: better forgings, closer control of temperature, and lower fuel costs result from using Wheelco Model 405 Capacitrols on this large bar-heating furnace. Bar stock heated to 2250-2450° F range is used to make forgings for automotive transmissions.

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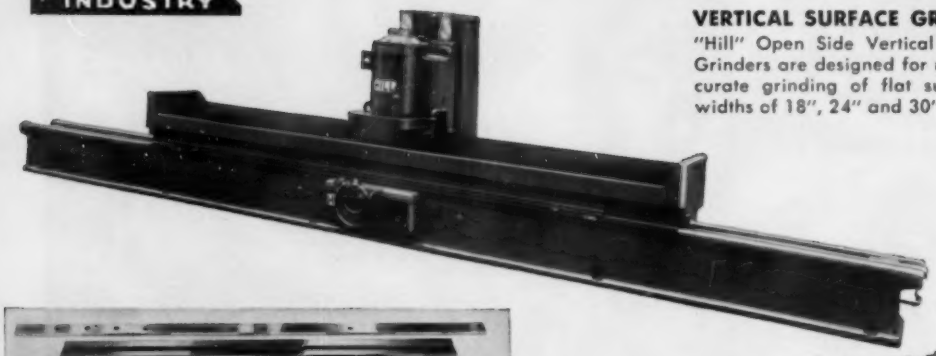
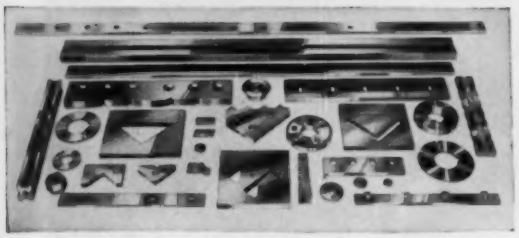


VERTICAL SURFACE GRINDERS

"Hill" Open Side Vertical Spindle Hydraulic Surface Grinders are designed for rapid stock removal and accurate grinding of flat surfaces. Furnished in table widths of 18", 24" and 30"; table lengths 60" to 240".



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"CLEVELAND" Knives and Shear Blades. Solid and laid steel shear blades; rotary slitting and side trimming knives; metal cutting machine knives.

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"Hill" Open Side Horizontal Spindle Hydraulic Surface Grinders for accurate grinding of flats, angles, irregular and special shaped surfaces. Furnished in table widths from 18" up to 36"; table lengths 60" to 240".

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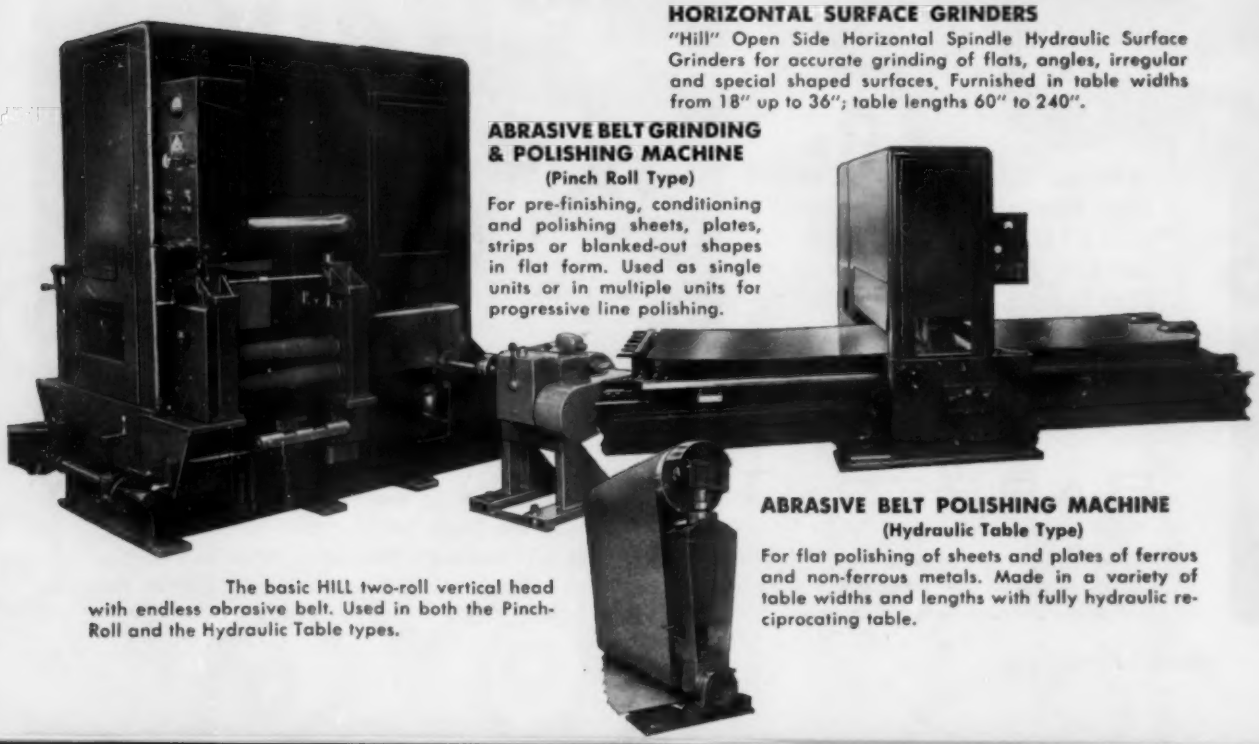

The basic HILL two-roll vertical head with endless abrasive belt. Used in both the Pinch-Roll and the Hydraulic Table types.

ABRASIVE BELT POLISHING MACHINE

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Tools for Industry

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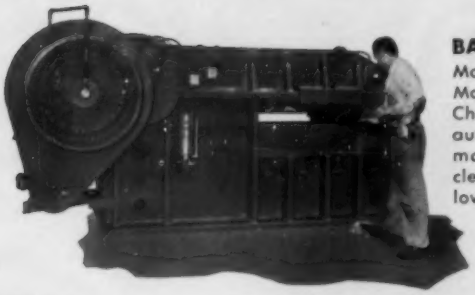

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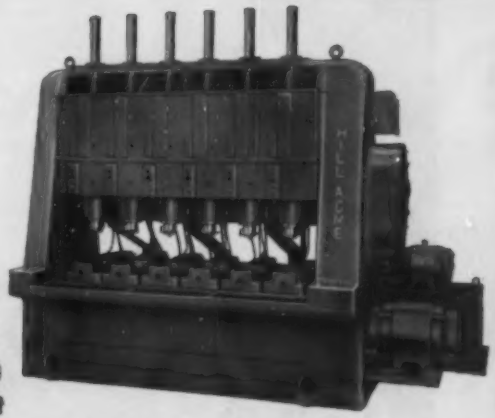

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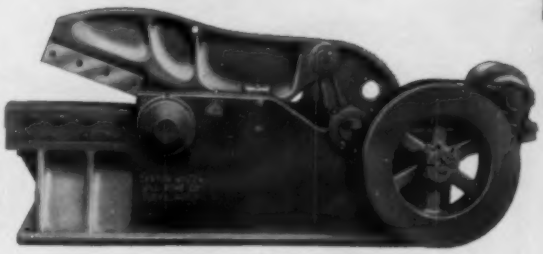

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"ACME" XN Forging Machines produce accurate, quality forgings for long uninterrupted periods. Massive construction and simplicity of operation insure years of trouble-free service. Built in 7 sizes from 1¼ to 5 inches. Also built as rivet or Ball machines.

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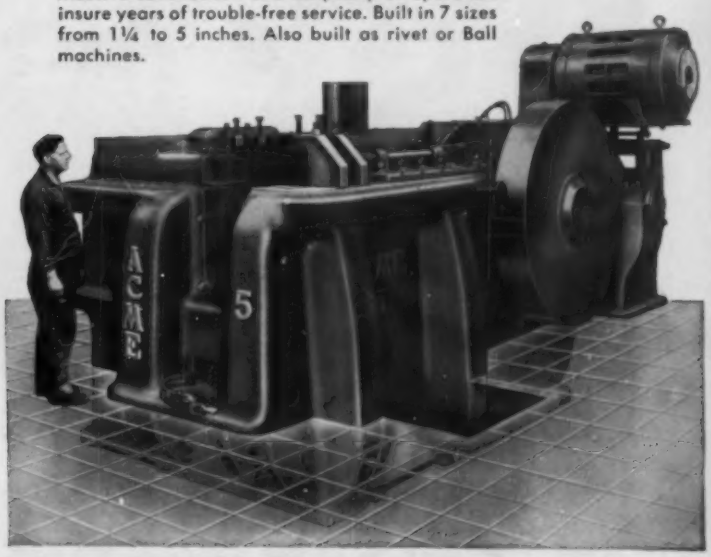

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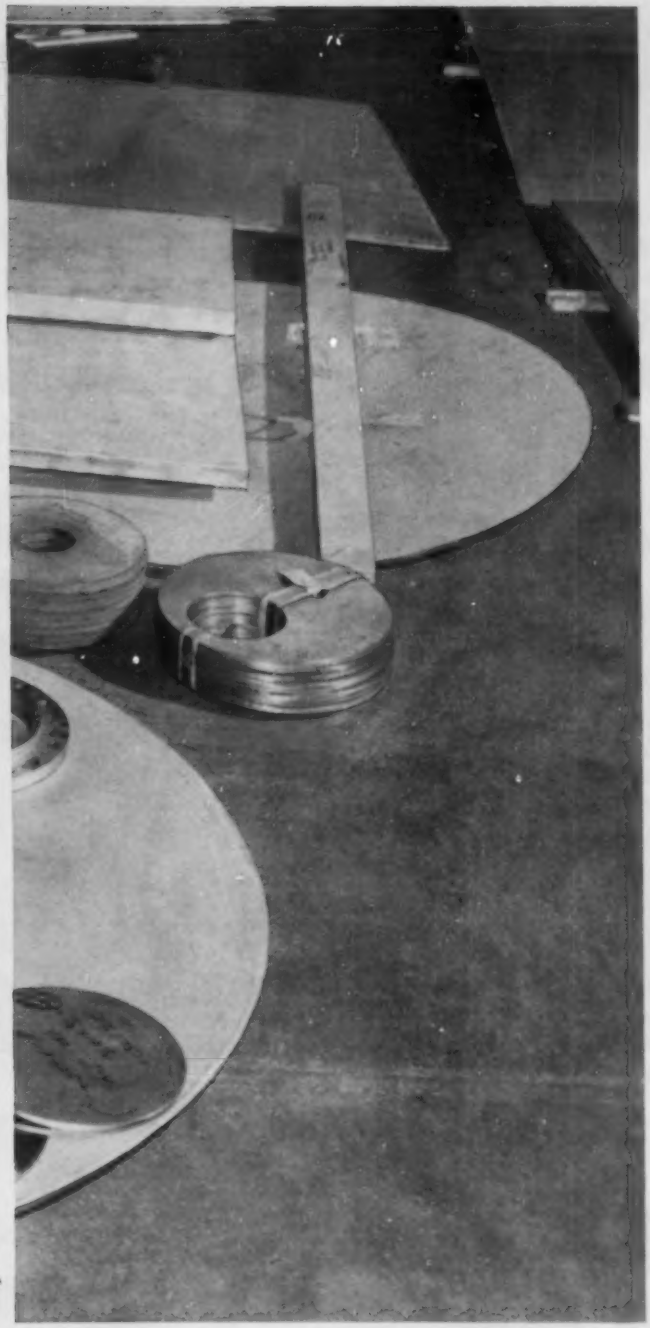

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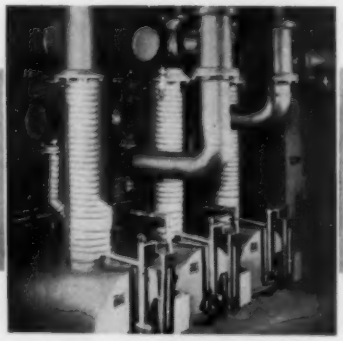
THE METALS INDUSTRY IS PROFITING FROM THE USE OF OTHER STOKES PRODUCTION EQUIPMENT



Vacuum Pumps. For rapid evacuation and holding high vacuums, Stokes offers mechanical pumps, and "Ring-Jet" oil vapor diffusion and booster pumps. New design affords 10 to 100% greater speeds.

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Exclude air and remove gases from metals, and you can create extra properties of strength and endurance that are unattainable by conventional techniques. This is one of the promising lines of metallurgical development that International Nickel Company, Inc. is investigating in their laboratories at Bayonne, New Jersey.

Using a Stokes Vacuum Furnace, the company is studying the effects of vacuum melting and casting on a variety of nickel base alloys such as Inco 700 and 713, destined for jet engines and other extreme temperature service. They also plan to examine the possibilities of vacuum melting of special nickel alloys containing oxidizable elements, stainless steels, cast iron and copper base alloys.

An induction heating crucible, inside the Stokes furnace, handles charges up to 50 pounds. By means of the Stokes vacuum lock, Inco technicians can manipulate the melt during heating . . . even take melt samples while high vacuum is constantly maintained.

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Powder Metal Presses. Cost savings and the compacting of incompatible alloys have made powder metallurgy an accepted process. Stokes offers the most complete line of presses in the industry.

REFERENCE DATA: Vacuum Furnaces—Catalog 790 • Microvac Pumps—Catalog 752 • Diffusion and Booster Pumps—Specification and Performance Data • Story of the Ring-Jet Pump—Booklet 756 • How to Care for Your Vacuum Pump—Booklet 755 • Vacuum Metallizing—Catalog 780 • Vacuum Calculator Slide Rule • Powder Metallurgy Today • Powder Metal Presses—Catalog 815

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SEAT-BELT MANUFACTURER LICKS CRITICAL PROBLEM WITH REPUBLIC ENDURO, TYPE 201

Here are the facts on a new and cost-cutting use of Republic ENDURO® Stainless Steel, Type 201, by Bunke-Musser Company, Jackson Center, Ohio, manufacturers of safety seat-belts for the automotive industry.

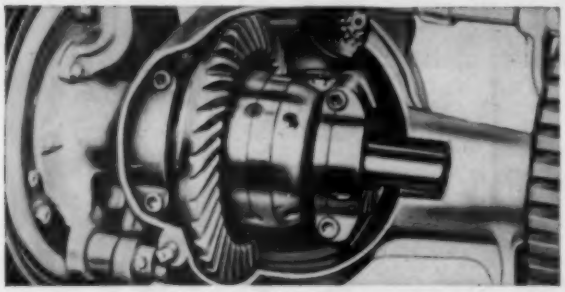
The most critical part of the entire assembly is the buckle. It must conform to Associated Seat Belt Manufacturers' specifications. These require that the buckles be subjected to a test pull of 1500 lbs., then reduced to 125 lbs. At this point, the pelican hook of the buckle must be capable of release at 45 lbs. pressure.

Prior to adoption of Type 201, another grade of stainless had been used. However, the slightly softer surface of this type resulted in a galling action at the fulcrum of the buckle when the release pressure was applied.

Bunke-Musser also experimented with carbon steel. But this required use of heavier gage, chrome plating and polishing, with the end result being much more expensive than stainless steel.

Now the company has standardized on Republic, Type 201, with excellent results. The buckles meet and exceed test specifications. The galling action has been eliminated. Tensile strength increased 200 lbs.

Types 201 and 202 are relatively new members of Republic's family of stainless steels. Republic Specialists will be happy to work with you in designing these new grades into your product. The 200 Series offers high strength, corrosion-resistance and easy forming on your present equipment. And they are readily available. Mail the coupon for more information, or if you would like a Republic Specialist to call at your plant. There's no obligation.



THERE'S NO SACRIFICE OF STRENGTH OR SAFETY in this drive axle designed from Republic Alloy Steel. In these fine steels you will find the highest strength values—plus an exceptionally high strength-to-weight ratio that permits transmission of hundreds of horsepower through tough, strong axles, shafts and gears, free from excess weight. Republic Alloy Steels are essential in designing smaller sections to carry heavier loads safely—essential in extending equipment life and reducing maintenance and replacement costs. Send coupon for data.

A BUILT-IN SAFETY FACTOR is one reason why Republic Nylok Nuts are being used in thousands of critical applications to resist shock, vibration and cyclic loading. The answer is in the nylon plug in one face of the nut which forces threads on other side tight against bolt or stud. Above, Nylok Nuts provide a powerful clamp action and keep vital steering tie-rod assembly securely in adjustment. Nylok Nuts can be removed for maintenance of parts, then re-used with no loss in holding power. And because either end is up they are ideal for automatic feeding and power wrenching. Send coupon for more facts.

STEEL

and Steel Products

REPUBLIC STEEL CORPORATION
Dept. C-2865,
3188 East 45th Street • Cleveland 27, Ohio

☐ Please have a Republic Specialist call.
Send more information on:
☐ 200 Series Stainless Steel ☐ Alloy Steels ☐ Nylok Nuts

Name _____ Title _____

Company _____

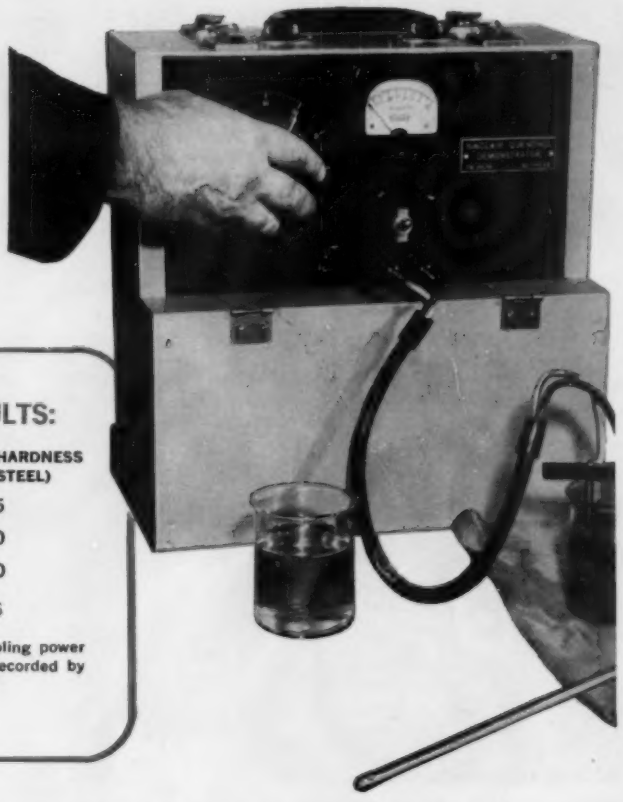
Address _____

City _____ Zone ____ State _____

TEST PROVES QUENCHOL'S HIGHER COOLING POWER!

10-MINUTE DEMONSTRATION

Compare any oil you now use with Sinclair QUENCHOL 521 in just 10 minutes! Right in your office or plant, Sinclair's new Quenchol Demonstrator will give you an accurate comparison of relative cooling power . . . show you how QUENCHOL can save money in your quenching operations!



A TYPICAL TEST SHOWS THESE RESULTS:

OILS COMPARED	COOLING POWER*	ROCKWELL C HARDNESS (SAE 1045 STEEL)
Competitive Oil A	576	23.5
Competitive Oil B	729	39.0
Competitive Oil C	1024	41.0
QUENCHOL 521	1369	54.5

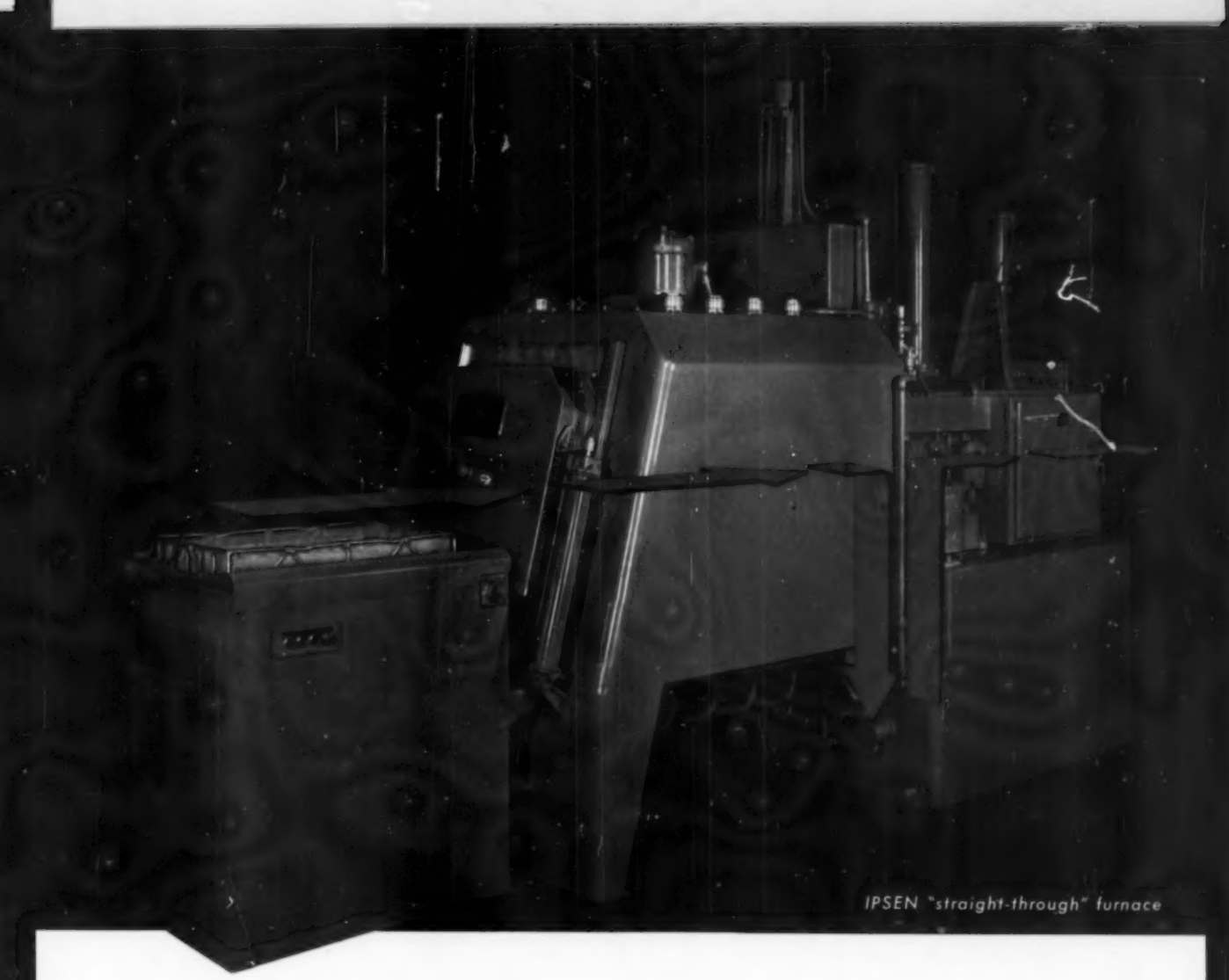
*Based on a recognized formula for determining relative cooling power value. Measured as the square of the current (I^2max.) as recorded by Quenchol Demonstrator.

ACTUAL PRODUCTION TOO... PROVES QUENCHOL SUPERIORITY!

In numerous production tests, QUENCHOL 521 has demonstrated its far superior quenching ability. All users report better results in the degree, depth, and uniformity of hardnesses obtained. Steels have included SAE 1035, 1040, 4140, etc. In many cases the superior results have been obtained while increasing working loads! Moreover, QUENCHOL's high sludge resistance, low acid formation characteristics and *high quenching reserve* keep it from deteriorating . . . extend QUENCHOL's amazing cooling power with longer service life!

For your own demonstration of QUENCHOL efficiency, and for more technical information on its properties, call your local Sinclair Representative . . . or write to Sinclair Refining Company, Technical Service Division, 600 Fifth Avenue, New York 20, N. Y. *There's no obligation.*

SINCLAIR METAL WORKING OILS



IPSEN "straight-through" furnace

What's your problem...

JOB LOT OR PRODUCTION HEAT TREATING?

Here is the furnace that brings in-line production to controlled atmosphere heat treating. In the same basic, compact, heat treating unit, work loads flow with automatic in-line movement from the loading platform . . . through the preheat chamber . . . to the heating chamber . . . into the quench . . . out through the discharge door . . . and then, if desired, on through washing and tempering units.

Total time required for heat treating is substantially reduced, work handling is cut to a minimum, and production costs are reduced.

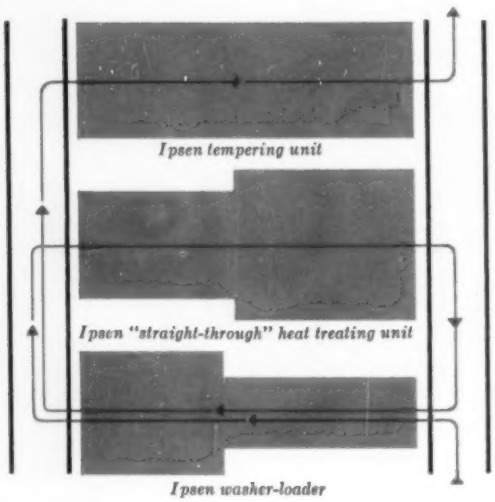
Ipsen "straight-through" heat treating units are suitable for job lot, semiautomatic, or 100% automatic production . . . they're equally efficient as multipurpose units for a wide variety of applications in a heat treating department . . . or for a single heat treating function in an automated production line.

AUTOMATIC Ipsen HEAT TREATING UNITS

following page shows floor plans for both job lot or continuous installations

HERE'S HOW YOU CAN ARRANGE IPSEN "STRAIGHT-THROUGH" FURNACES FOR DIFFERENT PRODUCTION REQUIREMENTS

for job lot production:

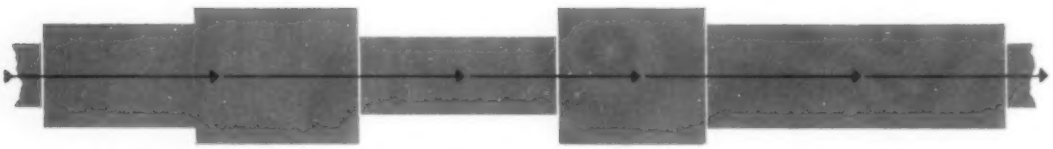


This arrangement includes an Ipsen Washer unit, an automatic "straight-through" heat treating unit, and a tempering unit installed side by side. Two transfer cars operate on crosstracks which connect the three units at both the charge and discharge ends.

Loaded work tray enters the washer . . . emerges from the discharge end to the transfer car which moves the tray to the charging end of the heat treating unit. Tray then enters the work chamber of the heat treating unit . . . passes from the discharge end to the transfer car, then back to and through the washer. The next transfer is into the tempering unit, and the work is ready for the next step of manufacture.

Automatic control of time, temperature, and atmosphere . . . plus the "straight-through" job lot processing features of Ipsen automatic heat treating units offer definite advantages over conventional "in-and-out" job lot type equipment.

for continuous production:



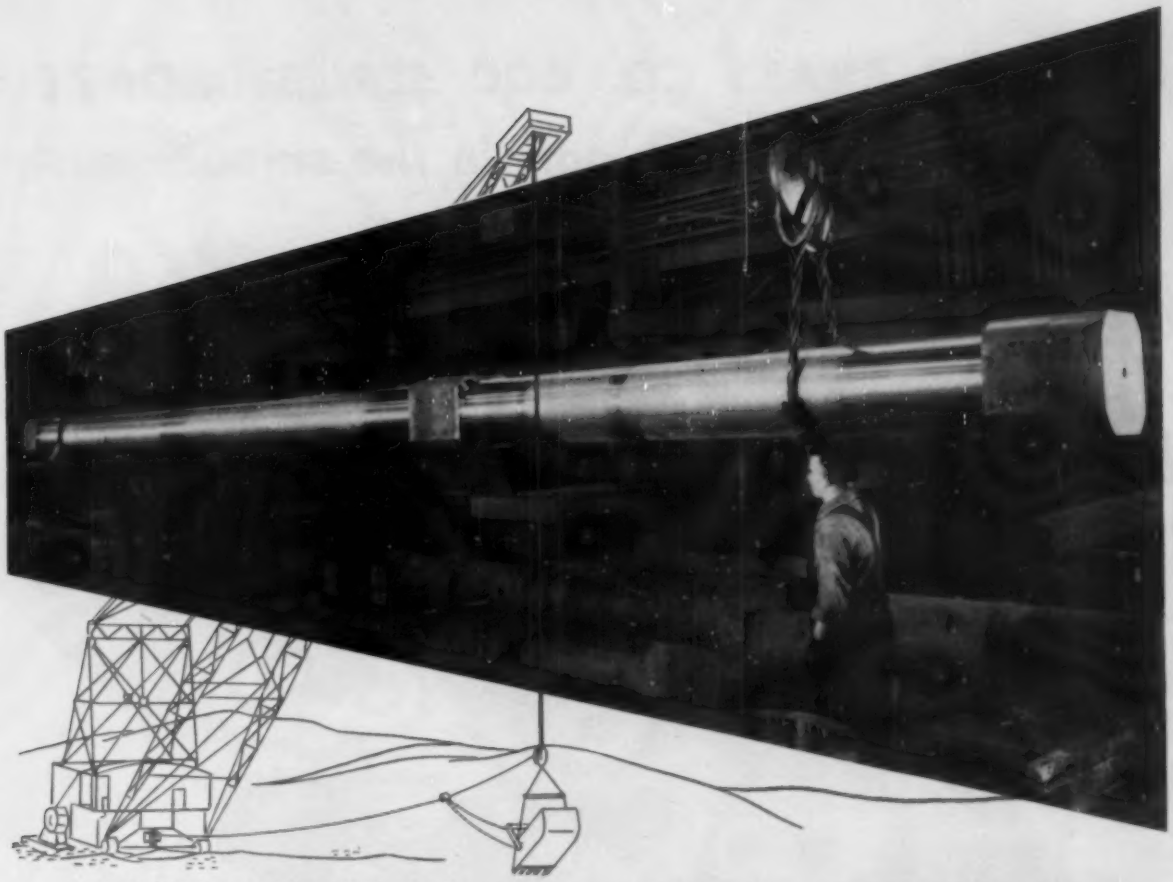
This is a completely automated installation. Special Ipsen-designed mechanisms receive the loaded work trays, move them into the furnace work chamber . . . later transfer them from the discharge end of the heat treating unit to a washer . . . then from the washer to the tempering unit . . . and finally out of the tempering unit to the next processing point.

Production flow is 100% automatic . . . continuous and uninterrupted. This type of heat treat line fits directly into an automated production line. Similar "straight-through," automatic, heat treating lines can be installed in straight, L, U, W, or O-shaped arrangements to suit the requirements of your plant.

AUTOMATIC Ipsen HEAT TREATING UNITS

Ipsen "straight-through" heat treating units (job lot or continuous) are already engineered . . . and can be built, delivered, and installed in a relatively short period of time. For detailed information, write, wire . . . or phone Rockford, Illinois, 5-9581.

IPSEN INDUSTRIES, INC. · 723 S. MAIN STREET · ROCKFORD, ILLINOIS



SAVE MONEY with FINKL FORGINGS

Manufacturers of earth moving equipment do!

• DIE BLOCKS • HOT WORK STEELS • FORGINGS • ELECTRIC FURNACE STEELS •

Walking draglines are ingenious, mobile monsters employed for digging and moving earth. Because of their size and applications, often in isolated areas, they must be dependable and steady in their operations. Only the best materials and workmanship will prevent costly downtime in the field.

Many of these machines employ Finkl forgings. The 48 foot "walker" shaft shown above transfers power from the engine to the walking mechanism of the dragline to move as much as 450 tons of equipment. Here the best materials and craftsmanship will prove the least expensive in the long run.

For over 78 years, Finkl has produced the best in cylinders, spindles, driveshafts, and special forgings both rough turned and finish machined. When you are considering forgings or die blocks, call your local Finkl representative.

A. Finkl & Sons Co.

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MUELLER BRASS CO. 600 SERIES BRONZE
the main working part in the smooth and
OCEAN CITY SPINNING REELS

600 Series gears prove ideal in heavy duty salt water models 300, R300, and 320 in which corrosion resistance and high strength are important.

Other typical "600" applications

FORGED GEAR powerful

The Montague-Ocean City Rod & Reel Co. of Philadelphia is proud of the fact that many fishermen are calling their famous Ocean City "300" series spinning reels "the most dependable spinning reels in America." Such praise justifies the very best components in a product—like the corrosion-resistant Mueller Brass Co. "600" alloy gear. Provides its own shaft and has an integral clutch which takes the driving force from the handle, and incorporates a cam which provides the oscillating motion of the spool for cross-winding the line. Bronze was chosen because of the need for maximum strength, long wear, and because it is such an excellent bearing material. This application dramatically points up the valuable properties of Mueller "600" series alloys.

There are countless applications of Mueller "600" series bearing alloys. Find out how you can utilize one or more of them in YOUR products. Because forgings can be made closer to the finish size in "600" series alloys than can sand castings, there is less waste, greater speed in finishing.

• WRITE TODAY FOR THE ENGINEERING MANUAL YOU NEED

Mueller Brass Co. Forgings
Engineering Manual H-58565 ☐

Tuf Stuf Aluminum Bronze Alloys
Engineering Manual H-58563 ☐

600 Series Bearing Alloys
Engineering Manual FM-3000 ☐

Copper Base Alloys in Rod Form
Engineering Manual FM-3010 ☐

METALS AND ALLOY REVIEW

by **FRANK M. LEVY**

Vice-President and Director of Research

Recently Ray Engelgau, who heads our statistical quality control procedures, and Amos Armitage from our machining department met in my office and we had a very interesting discussion on our new "S-C" rod. The term "S-C" is derived from the fact that it is produced from billets that are cast semi-continuously. In addition, we use the letters "S-C" to indicate its "super cutting" qualities which is one of the outstanding characteristics of this rod. We have definitely proved these qualities in some very exhaustive tests, one of which I'd like to tell you about here.

Experience has shown that it is difficult to control dimensions within close tolerances on machine parts involving internal forming operations. Amos had run into exactly that trouble with a certain hydraulic fitting made from rod that required a fairly close dimensional tolerance on the internal formed diameter. So, we decided to make a comparison test by machining the part from rod made by the conventional method and from rod produced by the S-C process. When rod made by the conventional method was machined, the parts could not be held within the specified tolerance range. The same machine, the same tooling and the same machine operator were used in this test, and when S-C process rod was substituted, the machine parts were well within the required tolerance range.

In addition, I just received a letter from a well-known equipment manufacturer who has been running tests on S-C rod. They reported that the incidence of tool trouble per 1000 forgings machined from S-C rod were approximately half that of forgings made from conventional rod. We think that is pretty good evidence that the rod made by our semi-continuous process is exceptionally uniform by all standards. Incidentally, our new billet casting department is quite a model of automation and has a number of interesting processes and features. Anytime you happen to be in our area we would be more than happy to show you through and explain the many points of this process that gives us what we firmly believe to be the best possible rod available today which of course is reflected in the quality of our forgings.

If you would like a folder that fully covers our semi-continuous process, just drop me a note and I'll see that one is sent along to you promptly. In the meantime, we'd like to have you investigate our super-cutting S-C rod because we think it will improve your product quality—and we've got the alloys to do most anything to meet the most exacting demands.

Thanks for your time.

MUELLER BRASS CO.

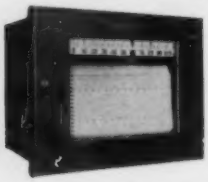
PORT HURON 28, MICHIGAN

199

Whatever your furnace needs for control—

There's good reason why more heat-treating furnaces everywhere are controlled by Brown instruments. First, of course, is performance . . . sensitive, precise control that meets the most exacting requirements of modern heat-treating techniques. And equally important is versatility. In this varied line of instrumentation you'll find just about everything a furnace could possibly need in the way of control.

Choose *ElectroniK* Strip Chart Controllers for detailed, long-term records . . . and a selection of control forms including electric systems of the contact, position-proportioning (*Electr-O-Line*) and time-proportioning (*Electr-O-Pulse*) types; and pneumatic control from two-position to full proportional-plus-reset-plus-rate action.



Choose *ElectroniK* Circular Chart Controllers for ease of scale reading . . . convenient daily charts; in a full range of electric and pneumatic control forms.

Note: the basic components of **all** *ElectroniK* models are interchangeable . . . to simplify and speed up service.

Choose *ElectroniK* Circular Scale Controllers where you want readability and control check at extreme distance . . . without need for a record. Supplied with all contact and proportional types of electric control.

Note: **all** *ElectroniK* models are available in both Standard and Precision Series.

Choose *Pyr-O-Vane* Controllers where you don't need a record but do need precise vane type snap action electric control by a millivoltmeter instrument... also available with pulse-type time proportioning action, in both vertical and horizontal models.

Choose the *Protect-O-Vane* Safety Cut-Off for simple, dependable excess temperature protection ... can be used with any temperature control to prevent furnace shut downs and loss of production.

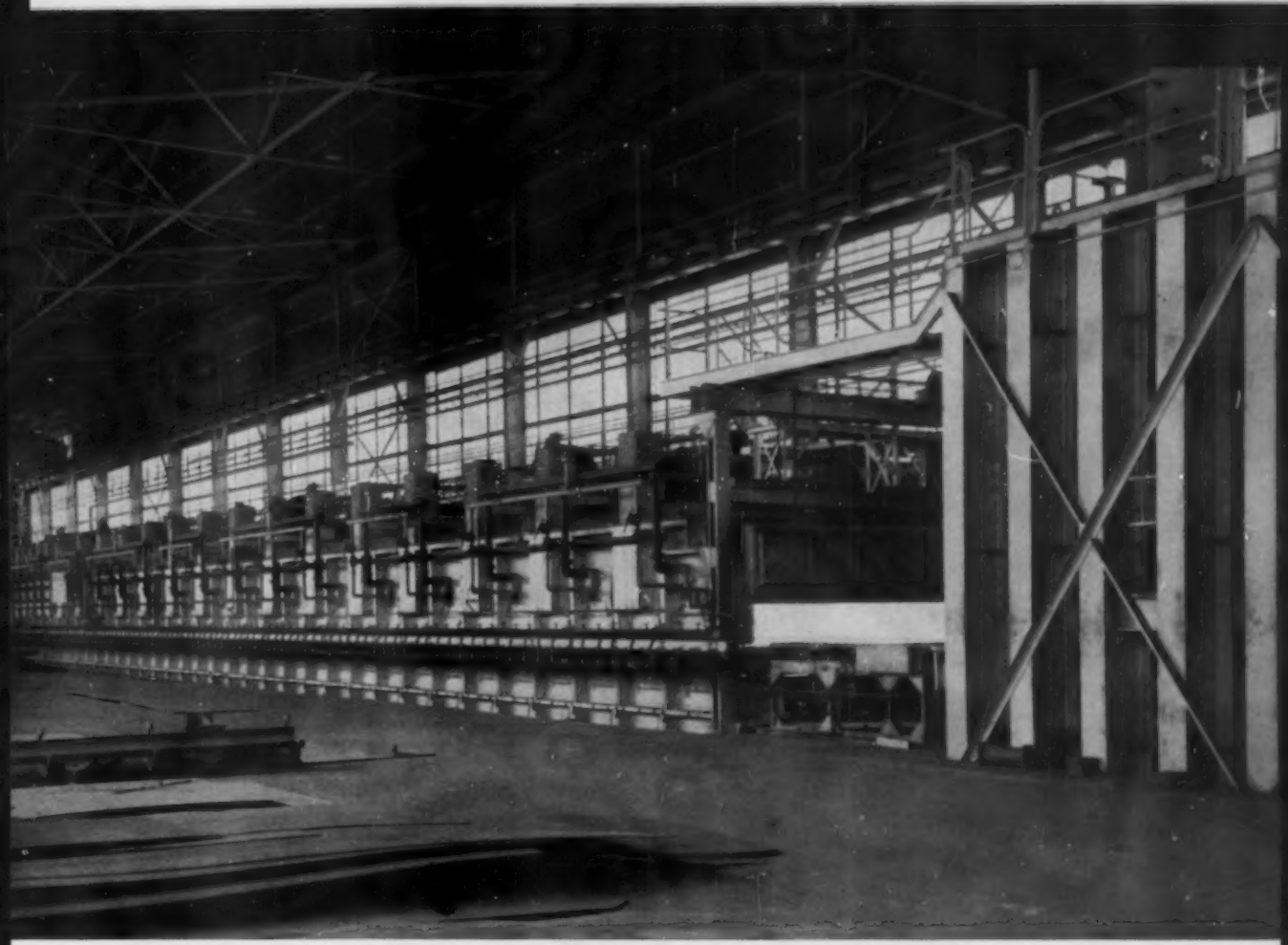
• • •

And ... for all your pyrometer supplies, investigate the convenience and economy advantages of the HSM Plan.

354 feet from loading end to quench press, *this continuous heat-treating line at Lukens Steel Co. processes wide steel plate quicker, more economically than ever before. Feature of the line is a Drever furnace, controlled by ElectroniK Air-O-Line instruments.*

130" steel plate heat treated to close temperature

In the control pulpit, *the operator can watch each zone temperature . . . clearly displayed on the circular chart ElectroniK controllers on the instrument panel.*



limits in Lukens' new 202′ furnace

STAINLESS steel plate up to 130 inches wide, 1 inch thick and 40 feet long is heat treated in a new line now operating at Lukens Steel Company, Coatesville, Pa. Designed by the Drever Co., Philadelphia, the line—longer than a football field—handles austenitic stainless alloy plates.

To handle the work that Lukens produces, the furnace was designed for accurate, flexible temperature control. 90 Bloom burners, firing either natural gas or No. 2 oil, supply heat under control of a battery of *ElectroniK* instruments. Through their *Air-O-Line* pneumatic control systems, these instruments regulate heat input to each furnace zone. They hold temperatures at the values set by the operator . . . throughout working ranges between 900 and 2000°F.

Close temperature control of this big furnace is the result of good furnace design . . . and top performance by instrumentation. It's the kind of job for which *ElectroniK* controllers have been chosen in thousands of metalworking and metal producing plants for more than a decade. Whether you're planning new equipment or modernizing, be sure that you select *ElectroniK* instrumentation . . . to be sure of the best in controls, made by the world's largest manufacturer of controls.

Let's talk over your specific control problems. Just call your local Honeywell field engineer . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Avenues, Philadelphia 44, Pa.—in Canada, Toronto 17, Ontario.

● **REFERENCE DATA: Write for Catalog 1531, "*ElectroniK* Controllers" and for Price List 56-1, "Furnace and Oven Controls."**

MINNEAPOLIS
Honeywell
BROWN INSTRUMENTS
First in Controls

NOW... two more reasons for retiring inadequate testing machines

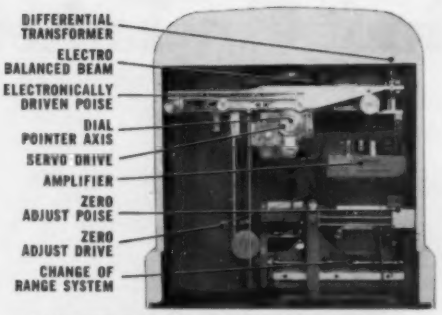
1. NEW SENSITIVITY
2. RAPID RESPONSE

VISIT RIEHLE AT THE WESTERN METAL SHOWS BOOTH 115

Here are the *sensitivity* and *rapid response* plus complete instrumentation you need for testing at elevated temperatures as well as at room temperatures.

With Riehle's new Electro-Balanced Indicating Unit, you know you are actually conforming with modern, more rigid testing requirements. No longer need you go on testing superficially with inadequate machines that just weren't intended for modern test procedures.

Riehle's new sensitivity and rapid response assure you of that flexibility and precision you must now have. The new Electro-Balanced Indicating Unit is available for both hydraulic and screw power testing machines — by Riehle.



SLIGHT MOTION AT BEAM END PROVIDES SUFFICIENT SIGNAL TO OPERATE THE SERVO MOTOR . . . AND MOVE THE POISE TO ESTABLISH FORCE EQUILIBRIUM.

NEW BULLETIN . . . MAIL COUPON

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Please send your free 4-page Bulletin RU-14-56 with full data on the new Riehle Electro-Balanced Indicating Unit.

COMPANY

ADDRESS

CITY ZONE STATE

ATTENTION MR.

APPLICATION and EQUIPMENT new products

Vacuum Furnace

High Vacuum Equipment Corp. has announced a new laboratory vacuum furnace which is suitable for melting, annealing, brazing, sintering and degassing by changing some of the furnace components. The standard model is a self-contained unit, with a

3-in. i.d. by 6-in. high stabilized zirconia crucible suitable for melting 12 lb. of steel at 3600° F. The furnace is tilt pouring, with a rotary mold turntable. Using the same cabinet, power supply and pumping system, the melting furnace becomes a heat treating, annealing, brazing or sintering furnace by removing the melting chamber and substituting a horizontal type muffle furnace having a hot zone of either 6 in. i.d. by 12 in. long or 6 in. i.d. by 24 in. long for processing at temperatures up to 1900° F. The vacuum system will evacuate the chamber to less than 1×10^{-5} mm. Hg when cold, dry and out-gassed.

For further information circle No. 597 on literature request card, page 48-B.

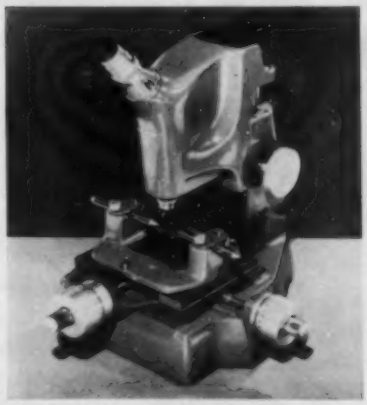
Cadmium Plating

A new cadmium plating process has been announced by Hanson-Van Winkle-Munning Co. The new Cadalume uses two brighteners. One is the make-up brightener and is used only when making up a new bath or converting an existing one. The other, called Cadalume brightener, is used for all maintenance additions. The process is used to protect iron and steel parts against corrosion, and nonferrous metals against surface tarnish, corrosion or galvanic couples formed in assemblies.

For further information circle No. 598 on literature request card, page 48-B.

Microscope

A new microscope for use by machinists and toolmakers in inspection and measurement of tools, drill jigs, templates and finished parts has been announced by the Bausch & Lomb Optical Co. Major advance lies in an illuminating system. The illumination source is built-in and the beam of light is directed down through the microscope objective, giving true vertical illumination. A collective mirror under the stage plate reflects the light back into the body tube. As a result, both the surface and the contour of parts may be viewed simul-

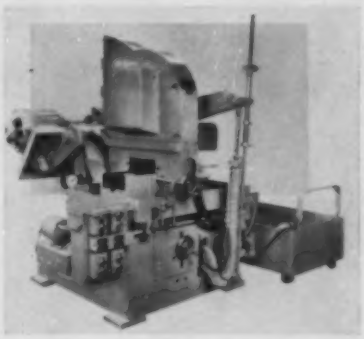


taneously. Standard magnification is 35X, but different objective and eyepiece combinations may be used to obtain other magnifications.

For further information circle No. 599 on literature request card, page 48-B.

Abrasive Cutting Machine

A new wet abrasive oscillating cutting machine has been announced by the Campbell Machine Div. This unit permits the cutting of large diameter



bar stock, tubing and other shapes, ferrous and nonferrous metals including corrosion-resisting steel as well as hardened or annealed steels of practically all analyses. This is an oscillating type machine in which the wheel feed and work clamps are hydraulically operated and the work bar is hand fed. Through its oscillating motion, the amount of abrasive wheel contact is reduced and cutting is performed with a minimum of wheel pressure. The Model 481 is furnished with a 25 hp., 180 rpm., totally enclosed, fan cooled motor to drive the abrasive wheel. The unit is 100 in. long by 85 in. wide by 84 in. high. Net weight with electrical equipment is approximately 6800 lb.

For further information circle No. 600 on literature request card, page 48-B.

Chilling Chamber

A new low-temperature chilling machine to cool metal specimens for impact testing has been announced by Cincinnati Sub-Zero Products. The new machine permits control of temperatures from +25 to —135° F. It may be moved to any location. It is

You don't have to wait for "wonder alloys"

Complete information on Carpenter High Nickel Alloys is contained in the most authoritative and useful set of booklets ever published on this type of alloys. We'll be glad to see that you get the data you need if you'll drop us a line on your Company letterhead.

Remarkable temperature compensation, controlled low expansion, high permeability, predictable response to very weak electrical signals, improved glass-to-metal sealing are here today.

In miniaturization, instrumentation, electronics . . . wherever the push is on to make products smaller, lighter, more accurate . . . new challenges are being met every day by Carpenter High Nickel Alloys.

Today, Carpenter has the most complete line of proven alloys available for these specialized applications. Let's discuss their part in your present and future NOW!

Carpenter STEEL

high nickel alloys

The Carpenter Steel Company, 133 W. Bern St., Reading, Pa.
Export Dept.: The Carpenter Steel Co., Port Washington, N. Y.—"CARSTEELCO"

24 in. high and the chilling chamber has a 2-cu.-ft. capacity. Thermal capacity is approximately 400 Btu. per hr. at —120° F. The system has two ¾ hp. hermetic motor compressors.

For further information circle No. 601 on literature request card, page 48-B.

Furnaces

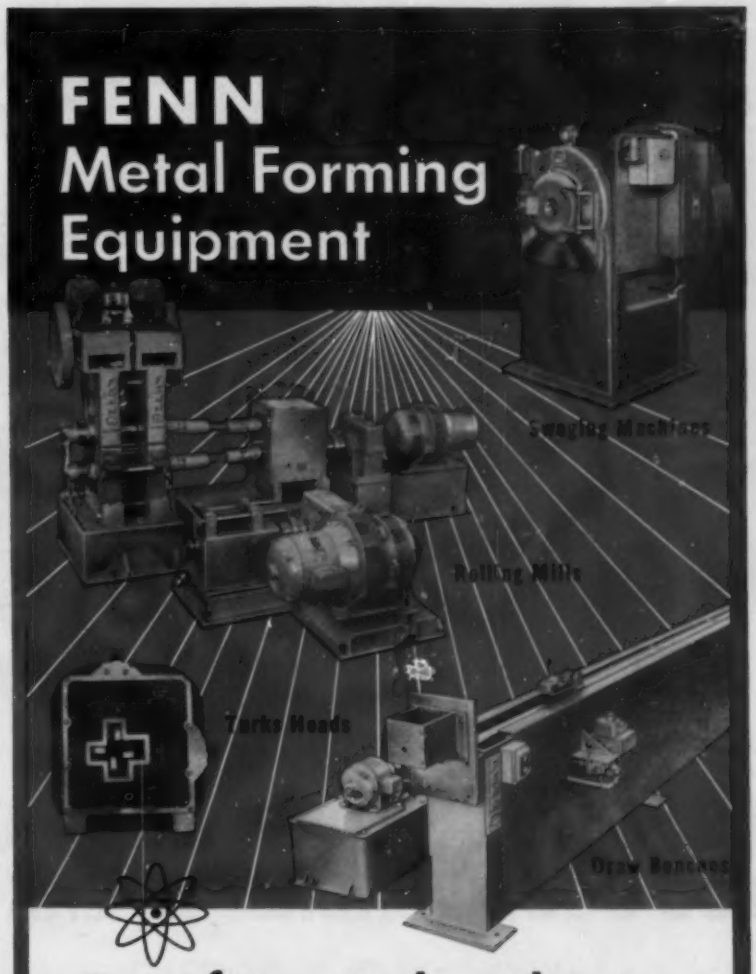
A new line of high temperature electric furnaces for research, quality control and small scale production has been announced by the Harrop Electric Furnace Div. Standard furnaces are available in six models, ranging in firing chamber size from 7 by 7 by 9 in. up to 36 by 36 by 40 in. Small

units are built with furnace and controls in one cabinet; larger models have a separate transformer housing and control panel. Standard equipment includes auto-transformer, circuit breaker, input ammeter, 36-step tap switch and temperature control system. Silicon carbide heating elements provide an operating range to 2800° F.

For further information circle No. 602 on literature request card, page 48-B.

Tester

The Allegany Instrument Co. has announced a prototype high rate tester for the measurement of tensile and compressive properties of material at high rates of deformation. It is capable of exerting loads at deformation rates as high as 6000 in. per min. To test a material, the operator clamps a specimen in the tension or compression jaws of the machine. He then depresses the calibrate button and a series of dots are placed on a photographic record by the electronic section of the high rate tester. These dots represent increments of stress in the vertical direction, and strain in the horizontal direction. The operator then depresses the operate button and the specimen is distorted at a preselected rate. Both the distortion and load are recorded on the photographic record as a stress-strain curve. In addition, timing dots are put on the record while the specimen



Core of Your Nuclear Planning

FENN PRECISION ROLLING MILLS are made in a complete range of sizes and types for laboratory, pilot run and production. They are designed and built to meet the requirements of nuclear metallurgy, including the newest and toughest metals. They can be supplied in both vertical and horizontal types with complete instrumentation for remote control and hooding where necessary.

FENN ROTARY SWAGING MACHINES are the invaluable precision production tools for nuclear metal forming . . . hot or cold . . . without producing chips. A complete range of sizes with capacities from ½" to 6" diameter. Models also available for internal reductions and with special length dies. Compact self-contained unit facilitates hooding.

FENN DRAW BENCHES AND TURKS HEADS—Fenn makes both hydraulic and mechanically actuated draw benches with capacities from 2,000 to 40,000 pounds pull. Variable drawing and return speeds to fit your specific requirements. Fenn Turks Heads, with infinite adjustment of rolls, are a valuable accessory to draw benches for producing almost limitless shapes in wire, rod, or tube.

For engineering services or literature, write
NUCLEAR MACHINERY DIVISION

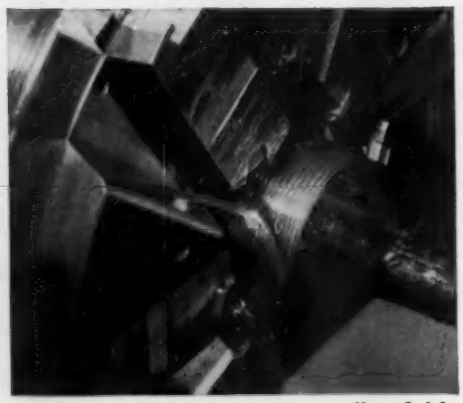
FENN

FENN MANUFACTURING CO. • 501 Fenn Road • Newington, Conn.

"WE'D BETTER GET TRANSPARENT SUNICUT FOR THESE JOBS WHERE WE HAVE TO SEE THE WORKPIECE. JOE JUST CAUGHT HIS NOSE IN THE THREADING MACHINE."
LOCKE

For precision cutting...

TRANSPARENT SUNICUT OILS ASSURE YOU GOOD VISIBILITY, PEAK PRODUCTION



Transparent Sunicut oils assure excellent finish in critical operations at close tolerances. Good visibility speeds production.

Transparent Sunicut® oils, including heavy-duty and dual-purpose oils, are available in many grades to suit your specific needs. They give outstanding results...especially where precision cutting is required.

Their transparency takes the "blinders" from work that needs close watching, permitting close product control, faster production, lower unit cost. Machine operators like Sunicut's "cleanliness." Most important, *transparent Sunicut oils assure you of good finishes.*

For full information about Sunicut cutting oils, call your Sun representative, or write to SUN OIL COMPANY, Philadelphia 3, Pa., Dept. MP-3.

INDUSTRIAL PRODUCTS DEPARTMENT

SUN OIL COMPANY

Philadelphia 3, Pa.

In Canada: Sun Oil Company Limited, Toronto and Montreal

SUNOCO®

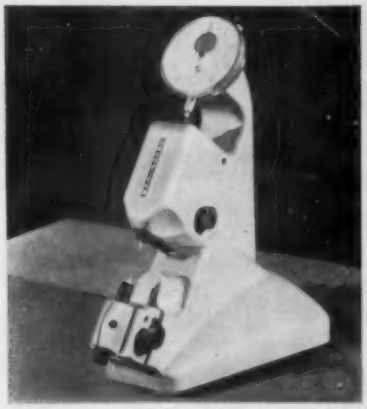
©Sun Oil Company

is being stressed. From this record, the rates of deformation, ultimate yield, elastic modulus, effect of deformation rates on elastic modulus and tensile strength, effect of temperature on tensile elongation are determined.

For further information circle No. 603 on literature request card, page 48-B.

Thread Checker

A new gage capable of checking and indicating pitch diameters of any specified pitch has been announced by the Sheffield Corp. It requires no special wires or attachments, can be operated mechanically to obtain pitch diameter readings from 0 upward on a dial graduated in 0.0001 in. The device uses one pair of gaging tips for each pitch of thread to be checked.



These tips have threaded shanks and are interchangeable to check pitch of any straight screw thread. A knob located on the gaging head enables the operator to select either a 16 or 40 oz. gaging pressure and other gaging pressures are available to meet special requirements. Parts are rolled slowly into position between the gaging tips and p.d. variations are read plus or minus on the dial.

For further information circle No. 604 on literature request card, page 48-B.

Phosphating Compound

The development of a compound to impart an iron phosphate coating of 80 to 120 milligrams in metal spray washing machines has been announced by Oakite Products. The new compound cleans and phosphates in a three-stage operation. It is used at 1½ to 2½ oz. per gal. of water in the first stage of the washing machine. It is followed by a hot water rinse, then by hot chromic acid or Oakite CrysCoat FH rinse. It will clean aluminum, zinc and brass, as well as ferrous metals.

For further information circle No. 605 on literature request card, page 48-B.

Recorder

A new 2-pen 2-zone recording instrument for comparative measurement in both the laboratory and on the production line has been announced by Weston Electrical Instrument Corp. This recorder is actually two independent instruments in one, housed in a case measuring 17¾ in. wide to fit standard relay racks. It employs two electronic amplifiers of special plug-in type for easy servicing and two separate measuring circuits with replaceable range standards for quick range change on either one or both zones as desired. The recorder is available with semi- or fully automatic standardization on potentiometer.

For further information circle No. 606 on literature request card, page 48-B.

Coating Testing

A new instrument for testing the hardness of nonmetallic coatings on metal has been announced by Crown Cork & Seal Co. The device can test all forms of coated metal, including flat stock. A stylus, linked by electronic circuit to an electronic tube, rests on the surface of the sample being tested. A spool-shaped weight is applied in gradually increasing degrees to the stylus. If the weight is sufficient to cause the stylus to pierce the coating and thus establish contact with the metal of the specimen, the thyratron tube closes a relay and a needle points to a figure on a scale, representing the number of grams of weight required to break through the coating.

For further information circle No. 607 on literature request card, page 48-B.

Continuous Casting

The development of a new continuous casting machine handling both heavy and light nonferrous metals has been announced by Lobeck Casting Processes, Inc. The machine is capable of producing billet sizes from 3 to 20 in. in diameter and

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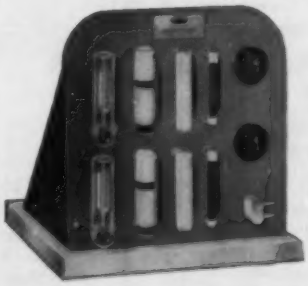
THE BURRELL CARBOTRANE

FAST, ACCURATE, EASY-TO-USE FOR CARBON DETERMINATIONS



The Carbotrane is a complete, compact carbon train for gravimetric carbons-by-combustion. It may be used with any laboratory furnace for carbons.

Uniformly pre-packed absorption bulbs are simply discarded when exhausted and quickly replaced with spares!

CAT. NO.	ITEM	PRICE
24-928	Carbotrane, Model 120—(double train)	105.00
24-923	Carbotrane, Model 110—(single train)	70.00

Prices listed are F.O.B. Pittsburgh, Pa.

Ask for Bulletin No. 323

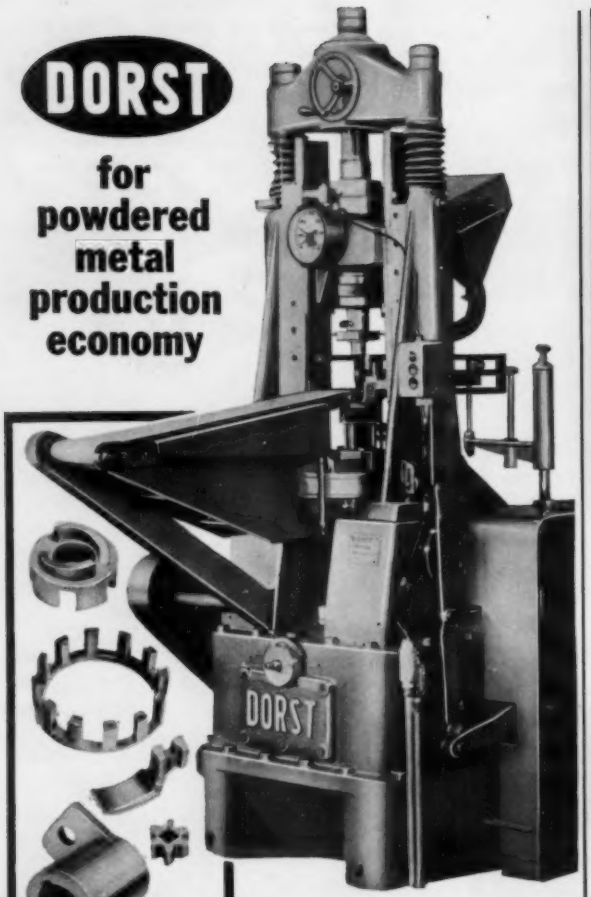
BURRELL CORPORATION

Scientific Apparatus and Laboratory Supplies

2223 Fifth Avenue, Pittsburgh 19, Pennsylvania

DORST

for powdered metal production economy



DORST AUTOMATIC PRESS TYPE DA

These are fully mechanical presses with hydraulic pressure indicator, utilizing a tooling system with full "floating-die" action and enabling the manufacturer to make parts to close dimensional tolerances. Dorst's compacting process assures uniform density and conformity from piece to piece in production runs. This tooling and compacting method has been recognized by leading authorities in this field for many years the world over.

FEATURES:

- High depth of fill from 5½" to 7-1/16" depending on size of press.
- Extremely simple set-up and change-over makes these presses economical for large and small runs.
- Optional equipment: Synchronized conveyor belt and pick-up mechanism to transfer fragile pieces to conveyor belt or to lift pieces from die cavity.

We have engineering facilities to aid the manufacturer in the production of intricately shaped forms, especially in the design and manufacture of tools. **Available sizes: 15, 25, 50 and 110 tons.**

Write TODAY for complete technical data

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DORST DIVISION
Sales and Engineering Organization for U. S. and Canada
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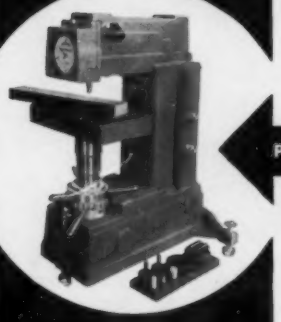
(REGULAR AND SUPERFICIAL)
1
Tester



KENTRALL MODEL CT-2

Hundreds of installations over the past few years have proved the economy of the only hardness tester which combines all scales of Rockwell Test (15 to 150 kg. loads).
The Kentrall cuts costs because it does the job of two conventional testers, requires only half the space and maintenance. Write for more detailed information, plus a list of prominent users who have switched to Kentrall.

TB148

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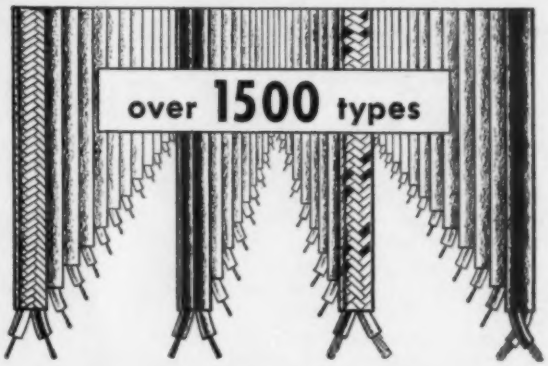


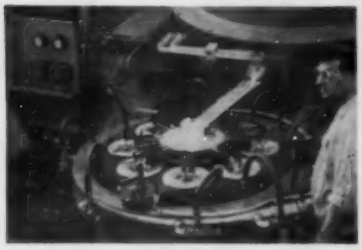
THERMOCOUPLE WIRE

Thermo Electric makes and stocks a countless variety of thermocouple and extension wires, both solid and stranded conductors—for *any* application, for *all* conditions. In fact, on T-E's shelves are over 1500 *different* wire combinations of advanced insulations, all standard calibrations, and gage sizes from 11-40—the widest selection known. Metallic armor overbraids of many hi-temp materials provide extra mechanical protection and electrical shielding. Whatever you need, in wire or multi-conductor cables, T-E has it. Prompt delivery.

Write for T-E Wire Bulletin 31-WS-H.

Thermo Electric Co. Inc.
SADDLE BROOK, NEW JERSEY
In Canada—THERMO ELECTRIC (Canada) Ltd., Brampton, Ont.

larger, and simultaneous casting of as many as 20 multiple strands is feasible. The automatic casting equipment can be arranged for either continuous or semi-continuous operations. Since the semi-continuous machines can produce multiple strands up to 25 ft. in length, it is usually not necessary to go to continuous arrange-

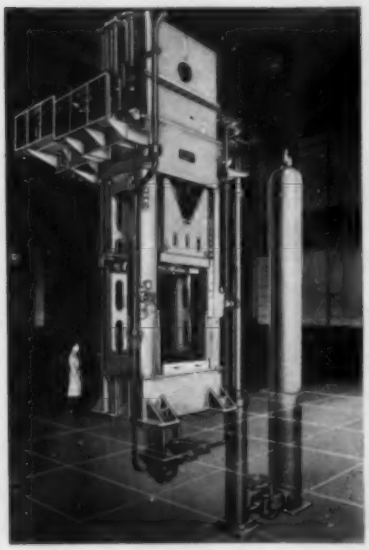


ment. Molten metal is fed into the molds under automatic flow control, maintaining a rate equivalent to the rate at which the solidifying castings move downward. The short length of the mold and its high thermal conductivity facilitate rapid solidification of the metal. The ingots are further cooled by controlled water sprays and finally, are immersed in the water contained in a welded steel tank.

For further information circle No. 608 on literature request card, page 48-B.

Press

A 1000-ton hydraulic press for hot piercing high-explosive 8-in. shells has been announced by Hydraulic Press Mfg. Co. It has a bed area of 66 by 60 in., 98 in. daylight, 60 in. stroke, and is equipped with a 150-ton hydraulic ejector. The main ram has a closing and return speed of 1000 in. per min. and a pressing speed of 600 in. per min. The press is equipped with a pressure vessel of sufficient



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capacity to perform a high-speed pressure stroke of 19 in. The power system requires 530 hp. for operation.

For further information circle No. 609 on literature request card, page 48-B.

Gas Generator

Hevi-Duty Electric Co. announces a new endothermic gas generator. It is a complete unit consisting of a catalyst-filled heating chamber, gas pump, heat exchanger and controls.

The generator produces 250 cu. ft. of atmosphere per hour. When used in a standard 230 volt, single phase circuit, it does not require a transformer.

For further information circle No. 610 on literature request card, page 48-B.

Counter

A 7-lb. portable electronic counter combining plug-in electronic decade and five-digit mechanical register has been announced by Performance Measurements Co. Design consists of an input amplifier, pulse shaper, plug-in electronic decade unit and register. It is capable of counting rates up to 12,000 per min. (200 per sec.) Count capacity is 999,999 with an accuracy of ± one count. It operates on 105 to 125 volts a.c. and has 90 volts d.c. accessory power.

For further information circle No. 611 on literature request card, page 48-B.

Cooling Compound

A new cooling compound for use while cutting and grinding aluminum has been announced by the International Chemical Co. According to the manufacturer, it penetrates to the

STRAITS TIN REPORT

New developments in the production, marketing and uses of tin

MALAYAN TIN BUREAU

Malaya's 780 active mines produced 62,295 long tons of tin-in-concentrates in 1956, the most since 1941. Output is continuing at a high level in 1957.

★ ★ ★

Straits tin is shipped from Malaya to the United States by three routes other than via Suez; so the closing of the canal has resulted in only slight delay in transit to Atlantic and Gulf ports, none to Pacific ports.

★ ★ ★

Straits, the world's best-known and most widely used grade of tin, is used in producing the tin plate for 9 out of every 10 tin cans made in the United States.

★ ★ ★

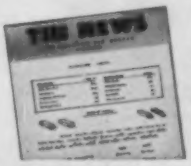
A new process for coating steel strip with tin was recently developed by the British Iron & Steel Research Association. Instead of being dipped in molten tin, the strip is passed between two rolls which convey tin from molten baths to both sides of the steel.

★ ★ ★

All of the millions of motor vehicles manufactured in the United States in 1956 contain tin—about 8000 long tons. New high-tin solders with unusually long life at temperatures as great as 223°F. have been developed for use in automobile radiators having operating pressures up to 16 psi.

★ ★ ★

A newly discovered alloy of zirconium, tin (4%) and molybdenum (1.6%) has four times the creep strength of pure zirconium at 930°F. This alloy can be readily rolled at 1470°F., and can be heat-treated to a strength of 140,000 psi.



Ask us to send you TIN NEWS, a monthly letter. It will keep you posted on tin supply, prices, new uses, and applications.

The Malayan Tin Bureau
Dept. 25C, 1028 Connecticut Ave., Washington 6, D.C.

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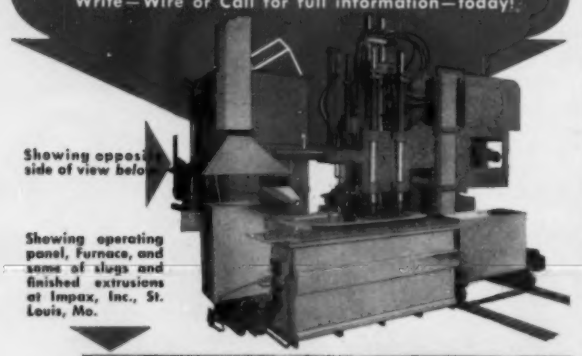
The One and Only Slug Casting Machine for Aluminum Forging and Aluminum Impact Extruders!

Here is Stroman's newest invention that casts slugs from ingots in one complete operation making it possible to produce perfect slugs ready for forging or extrusion, at a speed heretofore thought impossible. Some sizes produced as many as 1500 pieces an hour . . . and a die can be constructed to fit your specific needs.

Operation is completely automatic, operation is simple, and it saves a tremendous amount of man-hours in production. It is foolproof, producing perfect slugs every time, for forging or extruding, with no return scrap metal.

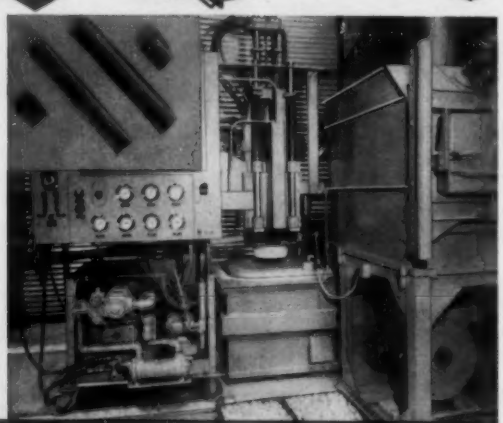
Let us show you the COMOCAST in operation . . . show you its efficiency and metallurgical perfection of each slug . . . even make some slugs to fit your products for you to try. Honest, it's the finest money saving machine you forgers or extruders have ever had presented to you.

Write—Wire or Call for full information—today!



Showing opposite side of view below.

Showing operating panel, Furnace, and some of slugs and finished extrusions at Impax, Inc., St. Louis, Mo.



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Franklin Park, Illinois

make hardness tests
ANYWHERE

with this lightweight, portable
NEWAGE TESTER

- no clamps, no jaws
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- no calculations or conversions
- no skill required
- accuracy guaranteed by individual calibration

available in scales corresponding to Rockwell and Brinell

Test any size, shape or type of metal anywhere! Use the versatile, 30 oz., portable, precision NEWAGE tester and eliminate the time, trouble and labor of getting work to a bench tester. Just press the hand grips and get answers in 30 seconds—inside or outside the plant, office or laboratory.

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NON DESTRUCTIVE MICRO-HARDNESS TESTER AND METALLURGICAL MICROSCOPE BY SHEFFIELD

This instrument determines hardness of precision-ground or lapped parts, fine wires, very thin sheet stock, cutting tool edges, ball bearing components as well as the more commonly tested parts.

Non-destructive because the indenting load ranges only from 25 to 1000 grams and the disturbance of the surface material is less than .000010". The spot to be indented can be located within .0002".

As a metallurgical microscope, magnifications of 200X and 400X are provided, with the option of using a camera for photomicrographs.

Write for Data Sheet to THE SHEFFIELD CORPORATION
Dayton 1, Ohio, U.S.A., Dept. 39

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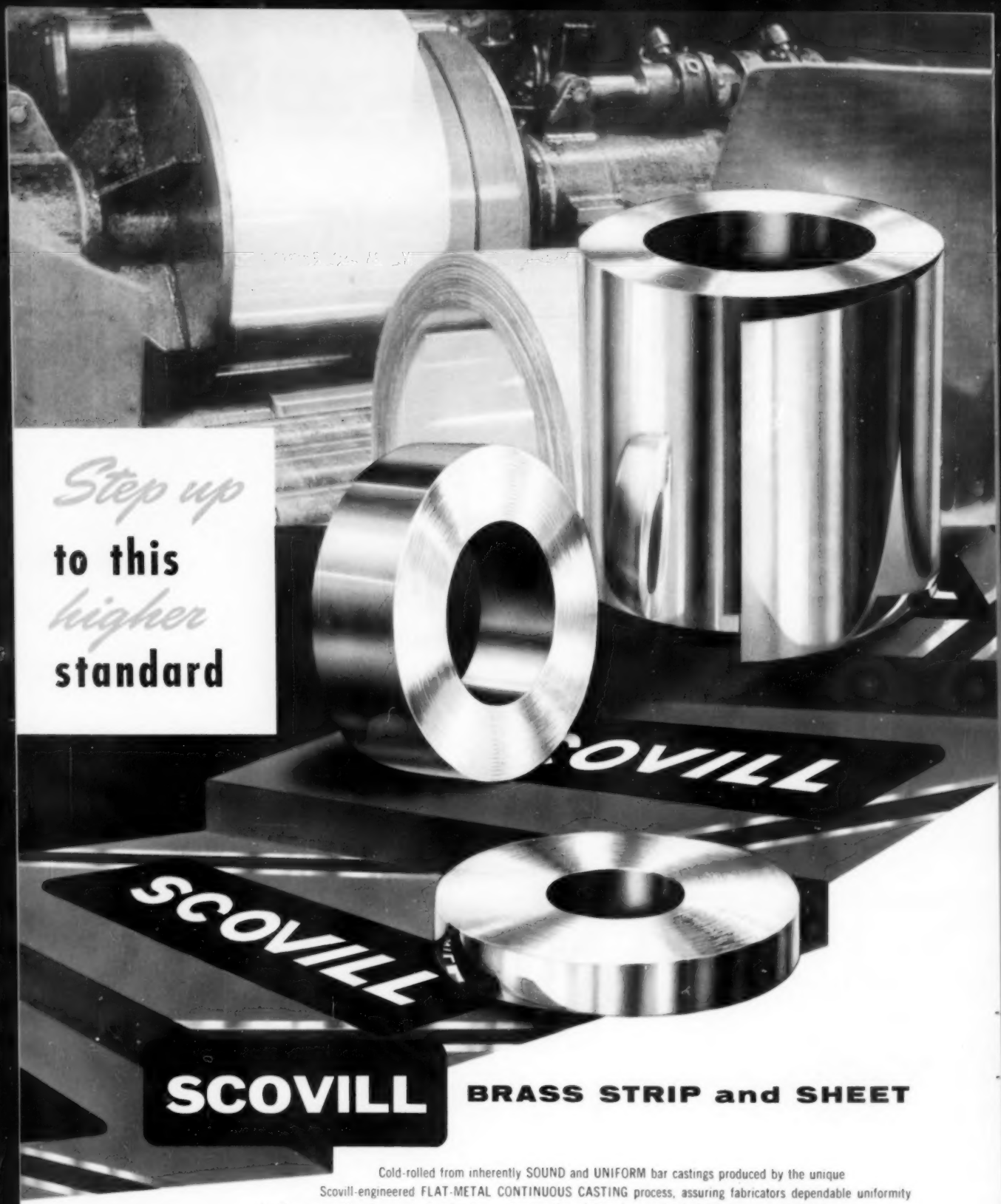

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Cold-rolled from inherently SOUND and UNIFORM bar castings produced by the unique Scovill-engineered FLAT-METAL CONTINUOUS CASTING process, assuring fabricators dependable uniformity in alloy composition, temper and grain size . . . freedom from internal or mechanical defects . . . in the industry's longest weld-free coils when needed . . . with rapid deliveries from fast production cycles. These and many other Scovill PLUS VALUES, including new modern packaging, are designed to

bring out the BEST in your fabricated products

Scovill Manufacturing Company, Mill Products Division, 99 Mill Street, Waterbury 20, Connecticut. Phone Plaza 4-1171.

1SC57

point of contact swiftly and prevents premature loading of grinding dust on the wheel. This increases the life of cutting tools by virtually eliminating the welding of chips. It is also claimed that this cutting compound prevents stain or discoloration. It is a special blend of mineral oils and synthetics that will not become rancid.

For further information circle No. 612 on literature request card, page 48-B.

Laboratory Furniture

Four extra-deep Formica bench tops to add work space to laboratory installations have been announced by Fisher Scientific. Manufactured in

2, 3 and 4 ft. widths and in a 5-sided corner-unit shape, the tops are 30 in. deep. A layer of aluminum foil backs up the Formica and it in turn is backed by a 9-layer plywood.

For further information circle No. 613 on literature request card, page 48-B.

Induction Heating

A new 400-cycle induction-type heating unit has been announced by Hobart Brothers Co. The unit permits preheating and stress relieving to be carried out in a continuous cycle without necessity of moving the weldment for furnace treatment or other operation. When the preheat

temperature has been selected, the controlling instrument heats to this temperature and holds it until welding begins. After the weld is completed, the instrument automatically starts the desired stress relieving program.

For further information circle No. 614 on literature request card, page 48-B.

new... booming... stainless steels call for alloy purity

and ELECTROMANGANESE® has it

Lower cost . . . better mechanical properties . . . and improved appearance are giving tremendous impetus to the new high-manganese stainless steels. Best of all, for those who have been working in the old high-nickel alloys, the new 200 Series requires no change in production operations, and possibly effects some savings.

But—high manganese content means *pure* manganese . . . electrolytic manganese. Most of the new alloys cannot tolerate more than a trace of carbon, phosphorous, or lead. Foote Electromanganese, with 99.98% manganese content, gives you this purity. Hydrogen is as low as 150 ppm, and even this can be reduced to 7.5 ppm in a *Hydrogen-Removed* Grade. Nitrided manganese is available in Foote's high-purity Nitrelmang®. But just as important as purity, and as a direct result of it, these Foote alloying agents enable you to get the necessary manganese content in the most economical way.

If you want to exploit these promising new steels, one of our engineers will be glad to contribute Foote's knowledge of more than 17 years experience in electrolytic manganese alloying. A letterhead request will bring information promptly from our Technical Literature Department, Foote Mineral Company, 424 Eighteen West Chelten Building, Philadelphia 44, Pa.

Foote MINERAL COMPANY

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RESEARCH LABORATORIES: *Berwyn, Pa.*
PLANTS: *Cold River, N. H.; Exton, Pa.; Kings Mountain, N. C.; Knoxville, Tenn.; Sunbright, Va.*

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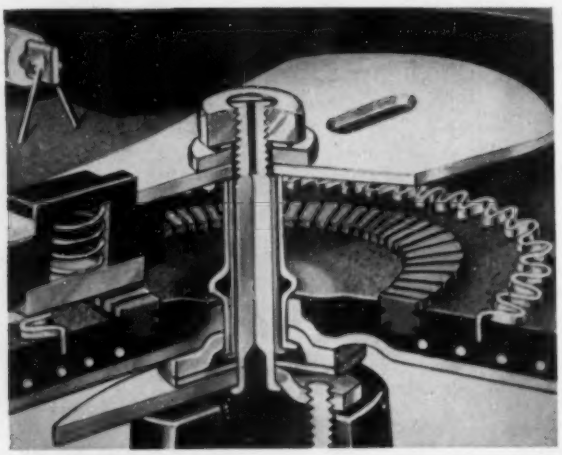
Extruded Shape Cuts Assembly Over Half

A Ward Leonard Type M Vitrohm rheostat using contacts made from extruded shapes

Ingenious application eliminates hand assembly, makes absolutely uniform stationary contacts in Ward Leonard power rheostats



CROSS SECTION VIEW of a Ward Leonard Vitrohm Type S rheostat showing how contacts are embedded in a vitreous enamel.

Ward Leonard Electric Co., Mount Vernon, N. Y., makes a line of high quality power rheostats marketed under the trade-name Vitrohm. Anywhere from 41 to 161 individual stationary contacts, or buttons, have to be embedded with their resistance elements in an insulating vitreous enamel—all contacts uniformly set and spaced, for uniform performance. Their patented process originally used buttons blanked out of sheet brass—hand assembled and spaced on a steel wire to hold them while the vitreous enamel was fired.

Ward Leonard refined the process and for four models now starts with the extruded shapes shown above. The stock is accurately slotted for correct spacing, forming a continuous line of buttons connected by a triangular "wire"—which is an integral part of the extruded shape. When sections are curved, the buttons remain uniformly spaced and oriented. After the button assemblies are embedded in the vitreous enamel, the connecting wire is easily milled off. Ward Leonard gets absolute uniformity with less effort and fewer rejects—it gets healthy dollar savings, despite the fact that more than half of the extruded shape is milled out.

Imagination applied to extruded shapes can pay big dividends—lower direct labor costs—fewer machining operations—less scrap—improved product quality. Your Anaconda representative will be glad to work with you. The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ont. 5886

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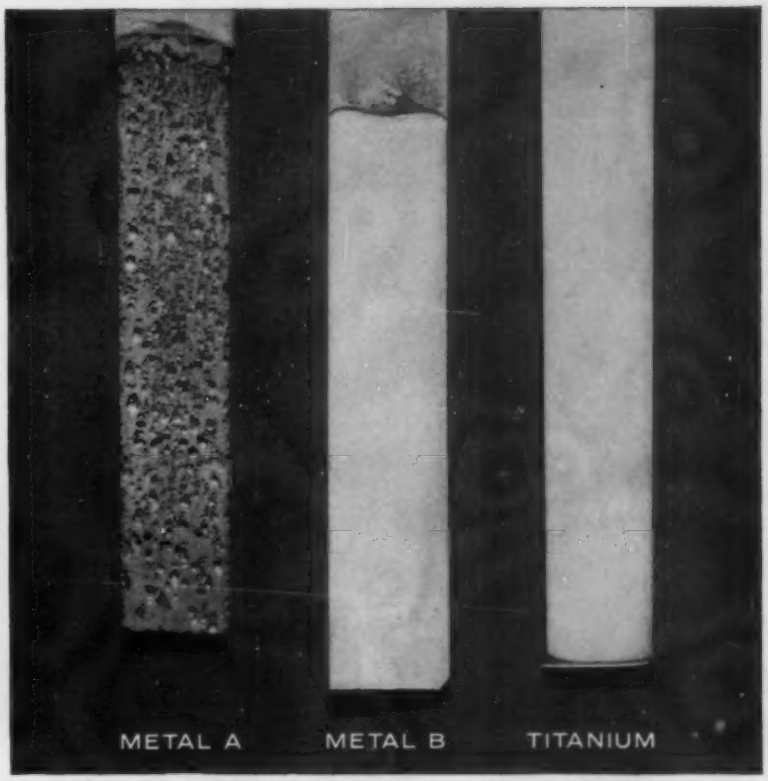
Short cuts to a finished product

Progress with
TITANIUM



Test strips of three different metals after partial immersion for 24 hours in the same solution containing 10% nitric acid and 20% ferric chloride. Only titanium was unaffected. Both metal "A" and "B" are commonly used in corrosive processing applications.

TITANIUM

...the lowest cost material of construction?

● Although known as a high-priced metal, titanium is actually the lowest-cost material available in a surprising number of applications. For titanium has exceptional resistance to many corrosive media that severely attack other specialty metals.

To evaluate the economies of titanium try it where you have severe corrosion problems. Test and operating data indicate outstanding performance in contact with some of the most troublesome industrial chemicals — nitric acid, moist chlorine, chlorinated organic or inorganic compounds, etc.

As to *original* cost of titanium, per-pound price is not indicative, since titanium weighs only 56% as much as steel. Also, fabrication and other costs of any equipment usually far outweigh the material costs. On the basis of typical processing equipment which has been produced, the use of titanium versus stainless steel increases original cost by a factor of 3. Where there are substantial savings in replacement and down-time, titanium quickly pays for itself. Titanium in several cases has lasted up to 15 times longer than conventional materials.

Let us help you evaluate titanium. It may well be the lowest cost material of construction for your processing equipment. You can obtain Mallory-Sharon titanium and titanium alloys in standard shapes. For booklet on Titanium Corrosion Properties write Dept. F-3.

TYPICAL PRESENT APPLICATIONS OF TITANIUM

Anodizing racks	Impellers
Condenser inserts	Piping
Filters	Process vessels
Heat exchangers	Steam jet diffusers

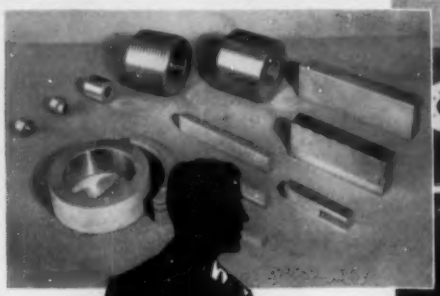
MALLORY Ti SHARON

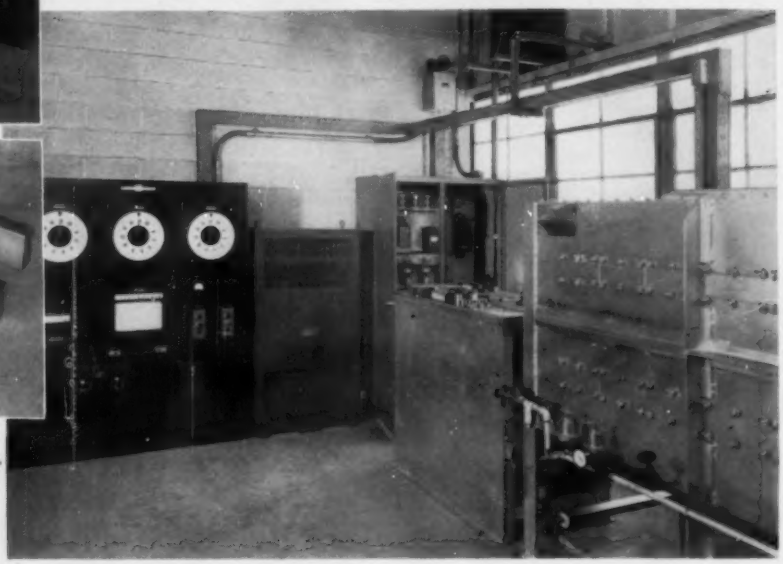
MALLORY-SHARON TITANIUM CORPORATION · NILES, OHIO

Producers of titanium and titanium alloy sheet, strip, plate, rod, bar, billets

GET "Uniformity of Austenitizing Cycle, Absolute Control of Surface Chemistry, Minimized Handling Damage"

George W. Lyman, Chief Engineer, Reed Rolled Thread Die Co.





HERE'S WHY...

REED ROLLED THREAD DIE COMPANY CHOSE HAYES EQUIPMENT TO HEAT TREAT THREAD ROLLING DIES . . .

The Reed Rolled Thread Die Company of Holden, Mass., recently installed a Hayes LAC furnace equipped with Hayes Ampro process atmospheric control to heat treat their flat, cylindrical and planetary thread rolling dies made of high carbon-high chrome steel.

Uniformity of the austenitizing cycle, absolute control of the thread surface chemistry, and reduced possibility of damage to the thread crests of the dies are the outstanding features which led to the selection of Hayes equipment and process.

Temperature in the three zone heating and the water-jacketed cooling sections of the furnace is closely controlled. Scaling of the dies has been eliminated, and the carbon content of the die surfaces is controlled by using dew point measurements to regulate the proportions of dissociated ammonia and propane in the furnace atmosphere according to the Hayes formula. By heating and cooling in the same piece of equipment, objectionable handling damage is minimized.

YOU TOO... can find the ideal solution to your heat treating problems at C. I. Hayes. The unique Hayes Laboratory contains an extensive line of production heat treating equipment on which to develop customized plant procedures. If existing equipment does not meet YOUR specifications, new equipment will be designed and built to suit.

YOU TOO... can be assured of GUARANTEED RESULTS designed to improve your product, increase output, and reduce unit costs. Let us show you what over fifty years experience in developing the well known line of CERTAIN CURTAIN electric furnaces and allied equipment can do for you. Write today!

FREE LITERATURE

ELECTRIC CERTAIN CURTAIN FURNACES

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Please send complete data. I am mostly concerned with the following heat treating procedures.

- ☐ High Speed Hardening
- ☐ Tool Steel Hardening
- ☐ Carbo-Nitriding
- ☐ Tempering
- ☐ Vacuum Heat Treating
- ☐ Bright Heat Treating
- ☐ Stainless Steel Heat Treating
- ☐ Sintering
- ☐ Copper Brazing and Soldering
- ☐ Lead Pot Hardening and Tempering
- ☐ Atmosphere Equipment
- ☐ Other

Name ..... Title .....

Company .....

Street .....

City ..... State .....

APPLICATION and EQUIPMENT new literature

615. Abrasion Tester
Bulletin 5409 on new model standard abrasion testing set describes machine and its operation. *Taber Instrument Corp.*

616. Abrasive Cleaning
Folder on Malleabrasive for airless blast cleaning equipment gives advantages, grades, equipment it may be used with and parts that may be cleaned. *Globe Steel Abrasive*

617. Abrasive Wheels
New 74-page abrasive wheel safety code includes scope and definitions, handling, storage, inspection, general machine requirements, safety guards, flanges, mounting, speed and general operating rules. *Grinding Wheel Institute*

618. Alloy Applications
New booklet on use of cobalt, nickel and iron-base alloys for machinery parts. Heat treatment, machining, grinding and forming of machinery parts. *Haynes Stellite Co.*

619. Alloy Cast Iron
64-page bulletin A-71 on engineering properties and applications of Ni-Resist. Corrosion data compared with gray cast iron. *International Nickel Co.*

620. Alloy Castings
8-page bulletin on alloy castings for heat treating. *Ohio Steel Foundry*

621. Alloy Castings
Bulletin 3150-G on castings for heat, corrosion, abrasion resistance. *Duraloy*

622. Alloy Steel
16-page book on type 9115 low-alloy high-strength steel. Properties, fabrications, welding. *Great Lakes Steel*

623. Aluminum
12-page booklet on extruded shapes, tube and pipe, coiled sheet, forgings and properties of aluminum alloys. *Revere*

624. Aluminum Cleaner
Data sheet on acid solvent cleaner for aluminum and its alloys. *Northwest Chemical*

625. Aluminum Die Castings
Bulletin on design and manufacture of aluminum die castings. *Hoover Co.*

626. Aluminum Extrusions
Folder lists alloys used, finishes, trade phraseology. *General Extrusions, Inc.*

627. Aluminum Finishing
Bulletin F9881 on process for applying conversion coating to aluminum and zinc. *Oakite*

628. Aluminum Paint
Bulletin on silicone base aluminum paint for use to 1700° F. Advantages. *Chem Industrial*

629. Analysis of Nickel Alloys
52-page Technical Bulletin T-36, "Methods for Chemical Analysis of Nickel and High-Nickel Alloys." *International Nickel*

630. Annealing Furnaces
8-page illustrated booklet on continuous annealing furnaces. Schematic diagrams, photographs, and actual production data. *Drever*

631. Atmosphere Furnace
Information on mechanized batch-type atmosphere furnaces for gas cyaniding, gas carburizing, clean hardening or carbon restoration. *Dow Furnace*

632. Atmospheres
12-page bulletin on use of protective atmospheres to prevent deterioration of metals during various heat treating processes. *General Electric*

633. Atmospheres
12-page booklet on design and use of special atmospheres for industrial furnaces. *Continental Industrial Engineers*

634. Barrel Finishing
20-page catalog of equipment and supplies. Abrasive and burnishing media. Variables in barrel finishing. *Globe Div., Casalbi Co.*

635. Batch-Type Furnaces
Bulletin SC-174 on furnaces in the operating range of 1400 to 1750° F. for various heat treating processes. Suction radiant tube fired units and mechanized systems. *Surface Combustion*

636. Beryllium Copper
12-page Bulletin 6 on advantages of beryllium copper and suggestions for ordering, including alloys, condition and temper, tolerances. *Penn Precision Prod.*

637. Black Oxide Coatings
8-page booklet on black oxide coatings for steel, stainless steel and copper alloys. *Du-Lite*

638. Brass Ingots
16-page booklet on new brass and bronze ingot produced by C. P. process. *I. Schumann & Co.*

639. Brazing
8-page reprint on dip brazing of aluminum assemblies. Design of parts, equipment used, maintenance, tooling. *Ajax Electric*

640. Brazing
8-page bulletin S-1050 on production brazing and soldering with automatic machines. Construction of custom models. *Selas*

641. Brazing
Bulletin 5889 on furnace and induction brazing installations and methods. *General Electric*

642. Brazing
How 28 stator blades are brazed to semi-circular brass shroud rings. Low Temperature Brazing News, No. 75. *Handy & Harman*

643. Brazing Alloys
Bulletin on application of six types of copper and silver brazing alloys. *United Wire & Supply*

644. Calibrator
Bulletin on calibrator for wire strain gages, their transducers and thermocouples. Specifications and controls. *Allegany Instrument Co.*

645. Carbide Cutters
Bulletin on milling cutters using throwaway carbide inserts. Prices and specifications. *Newcomer Products, Inc.*

646. Carbides
76-page catalog of sintered carbides, hot pressed carbides, cutting tools, drawing dies, wear resistant parts. *Metal Carbides*

647. Carbon Control
Technical report on instrument for control of carbon potential of furnace atmospheres. *Lindberg Eng'g*

648. Carbonitriding
Literature on Ni-Carb (carbonitriding) treatment for surface hardening. *American Gas Furnace*

649. Castings
Literature on shell or sand castings of ArmaSteel, malleable iron or gray iron. *Central Foundry Div.*

650. Chromate Finishing
File on chromate conversion coatings for prevention of corrosion and paint-base treatment of nonferrous metals. *Allied Research Products*

651. Chromium
Mining of chromium ore in Rhodesia described in Vancoram Review, Fall & Winter 1956. *Vanadium Corp.*

652. Chromium Stainless
12-page book on fabrication and use of Type 430 stainless steel. *Sharon Steel*

653. Chromizing
4-page folder describes how to make iron powder components resistant to rust and wear. *Chromalloy Corp.*

654. Coatings
New 4-page catalog on heat-proof protective coatings. Basic types, applications, methods of applying and temperature ranges. *Markal Co.*

655. Coatings
New bulletin gives uses of various conversion coatings for zinc and cadmium. *Chemical Corp.*

656. Compressors
12-page data book 107-D gives engineering information on characteristics of turbo-compressors. 18 types of application described. *Spencer Turbine*

657. Continuous Casting
24-page book, "Better by the Mile," describes how the Rossi continuous casting machine works. History of continuous casting. *Scovill Mfg.*

658. Controlled Atmospheres
Bulletin on Dewpointer for reading of atmosphere in field and laboratory. Readily portable, operating on a.c. or enclosed battery. *Illinois Testing Labs.*

659. Controlled Atmospheres
Illustrated literature describes controlled atmosphere installations. *Gas Atmospheres, Inc.*

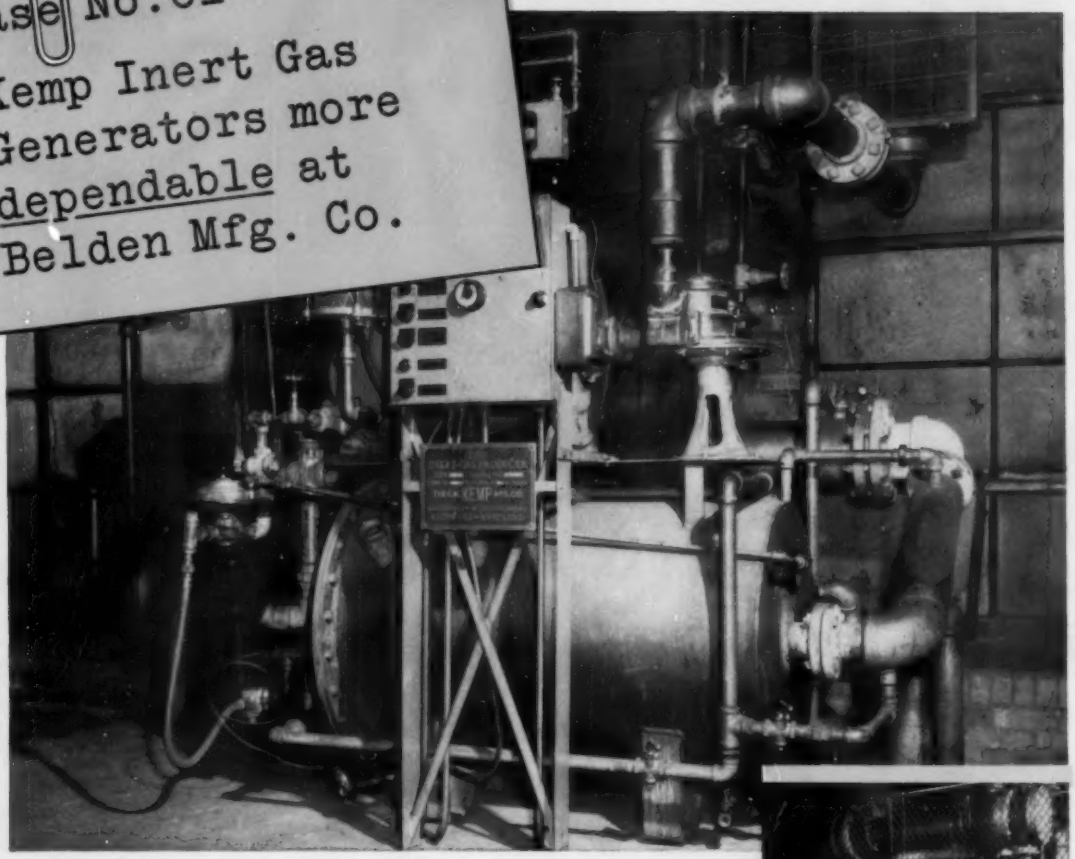
660. Controls
56-page catalog 857 of automatic controls for heating and industrial applications—pressure, temperature, liquid level, etc. *Mercoid Corp.*

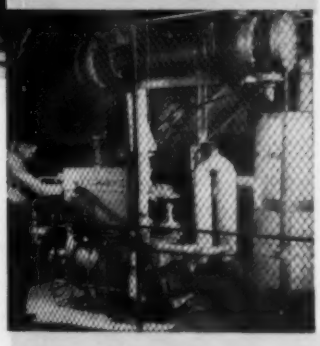
661. Conveyors
Bulletin MF-200 on conveyor standardization describes prefabricated sections for making customized conveyors. *May-Fran Engineering*

662. Coolants
Catalog on compounds for rolling, blanking, forging, extrusion, stamping,

Case No. 61

Kemp Inert Gas Generators more dependable at Belden Mfg. Co.





Generator on first floor of plant is enclosed in wire cage to prevent tampering with controls.

How Belden utilizes two Kemp Generators in annealing copper wire

Annealing copper wire necessitates cooling in an oxygen-free atmosphere to prevent harmful oxidation. For the required protective atmosphere in this process, the Belden Mfg. Co., Chicago, Ill., generates its own inert gas. But the generating equipment formerly used by Belden did not operate reliably . . . results were erratic. So Belden installed two Model MIHE Kemp Inert Gas Generators to handle this important job.

And Kemp *Handles* the Job

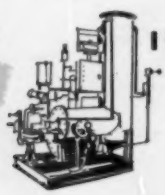
These two Kemp units assure Belden of a *dependable* inert supply. They deliver a more constant flow at the rated pressure . . . have been operating smoothly and satisfactorily since installation. Kemp's ability to produce a chemically clean inert at a *specific analysis regardless of demand* eliminates the danger of fluctuation at a critical stage.

Kemp Units Engineered for Service

Like Belden, you specify reliability when you specify Kemp. Every Kemp design includes the Kemp Industrial Carburetor for complete combustion without tinkering, without waste . . . for simplified installation and maintenance. Every Kemp design includes the very latest fire checks and safety devices. Annealing, hardening, sintering—whatever your problem, find out today how Kemp engineers can help you.

For more complete facts and technical information, write for Bulletin IB-11: **THE C. M. KEMP MFG. CO., 405 East Oliver Street, Baltimore 2, Md.**

KEMP OF BALTIMORE



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METAL MELTING UNITS • ADSORPTIVE DRYERS
SINGEING EQUIPMENT

drawing, cutting and grinding. Cleaning, etching and stripping chemicals. *International Chemical Co.*

663. Copper Alloys

40-page technical data book on eleven copper alloys. Properties, cleaning, annealing. *Seymour*

664. Copper Alloys

60-page catalog on phosphor bronzes, nickel silvers, beryllium copper, cupronickel. Chemical and physical data. Engineering tables. *Riverside Metal*

665. Creep Testing

Bulletin 4208 on five types of creep testing machines for standard sized metal specimens. *Baldwin-Lima-Hamilton*

666. Decarburization

8-page booklet on effects of decarburization on tool steels tells what it is and what can be done about it. *Carpenter Steel*

667. Definitions

36-page glossary of over 150 terms on cast iron. *International Nickel*

668. Descaling Process

8-page bulletin on sodium hydride descaling process for ferrous and nonferrous metals. *DuPont*

669. Descaling Titanium

Bulletin 25-T on salt descaling of titanium and titanium alloys. History, recommended procedure, problems. *Hooker Electrochemical*

670. Die Casting

New Bulletin No. 5700 on cold chamber die casting machines. Cutaway view shows construction of machine. *Hydraulic Press Mfg. Co.*

671. Electric Furnace

Bulletin on box-type, pre-heat and hardening furnace with automatic atmosphere contamination control. *Pacific Scientific*

672. Electric Furnaces

Catalog of electric furnaces and ovens for hardening, tempering, annealing, drawing, drying, baking, enameling. *Cooley Electric Mfg.*

673. Electric Furnaces

8-page Bulletin 570 on heat treating, melting, metallurgical tube, research and sintering furnaces. Custom designs for special requirements. *Pereny*

674. Electric Furnaces

Data sheet describes and gives specifications of standard non-metallic resistor furnaces. *Harrop Electric Furnace Div., Harrop Ceramic Service Co.*

675. Electrocoated Wire

8-page bulletin on new wire materials —Nickelply and Brassply, electrocoated steel wire. How it may be formed bent and twisted without breaking the coating. *National Standard*

676. Electrodes

8-page reprint on rate at which arc welding electrode melts in submerged arc welding. *Linde Air Products Co.*

677. Electron Tubes

12-page bulletin in industrial use and proper care of electron tubes. Log sheets for tube life records. *Machlett Laboratories*

678. Electroplating

Bulletin on electroplating lists key characteristics of 16 processes. *Hanson-Van Winkle-Munning*

679. Fasteners

32-page catalog 55 on parts for welding. Index includes small picture of each part. Custom parts. *Ohio Nut & Bolt*

680. Ferro-Alloys and Metals

104-page book gives data on more than 250 different alloys and metals produced by the company. *Electro Metallurgical*

681. Finishes

Pocket-sized booklet covers blackening compounds, alkaline cleaners, strippers, lacquers, enamels, rust removers. *Enthone*

682. Finishing

Technical data folder on Roto-Finish process, chips and compounds. Line of standard and special machines. *Roto-Finish Co.*

683. Firebrick

28-page bulletin R-34 on properties and characteristics of 5 kinds of firebrick. Typical applications. Tables of brick quantities for arches of different sizes and shapes. *Babcock & Wilcox, Refractories Div.*

684. Forging

4-page brochure on process for cold forging superalloys. Case histories. *Impact Products, Inc.*

685. Forgings

Series of articles on modern forging methods. *Hill Acme*

686. Forgings

Handsome 32-page brochure on large forgings for turbine shafts, rotors, drop hammer anvils, rolls. *U.S. Steel*

687. Forgings

12-page booklet on how forged weldless rings and flanges are made. Case histories. *Standard Steel Works Div., Baldwin-Lima-Hamilton*

Acoustica's low cost Ultrasonic Cleaning Console (PP-1) entirely self-contained mobile machine cleans completely assembled relay assemblies in above photo. Features three gallon cleaning tank, recirculating filter system, reliable magnetostrictive transducer with 1600 watt peak power generator. Operates immediately from 115V, 50-60 cps, as delivered.

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APPLICATIONS

CLEANING Ultrasonic "cold boiling" in common solvent or detergent solutions literally tears away grease, scale, and dirt in a matter of seconds from precision gear assemblies, sheet and strip metals, castings and other difficult-to-clean products. Ultrasonic cleaning saves disassembly and assembly labor, chemicals and floor space.

SOLDERING Ultrasonically agitated solder permits fluxless joining of similar and dissimilar metals such as aluminum, copper and other non-ferrous metals. This method prevents oxides from forming during soldering and allows wetting action to take place.

PLATING Ultrasonic energy gives a more uniform, non-porous plating job at lower current densities, thus saving time, labor, machinery, and chemicals.

DRILLING Ultrasonic motion, reciprocating rather than rotary, makes possible drilling of the most intricately shaped holes in hard as well as brittle materials, including glass, ceramics, tool steel, jewels, and carbides.

ACOUSTICA ASSOCIATES, INC. Glenwood Landing, Long Island, N. Y.

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- ☐ PLATING
- ☐ SOLDERING
- ☐ DRILLING
- ☐ GRINDING
- ☐ PICKLING
- ☐ IMPREGNATION
- ☐ FEED WATER DEGASSING
- ☐ LIQUID LEVEL SENSING
- ☐ DEGASSING MELTS
- ☐ CHEMICAL PROCESSING
- ☐ QUENCHING

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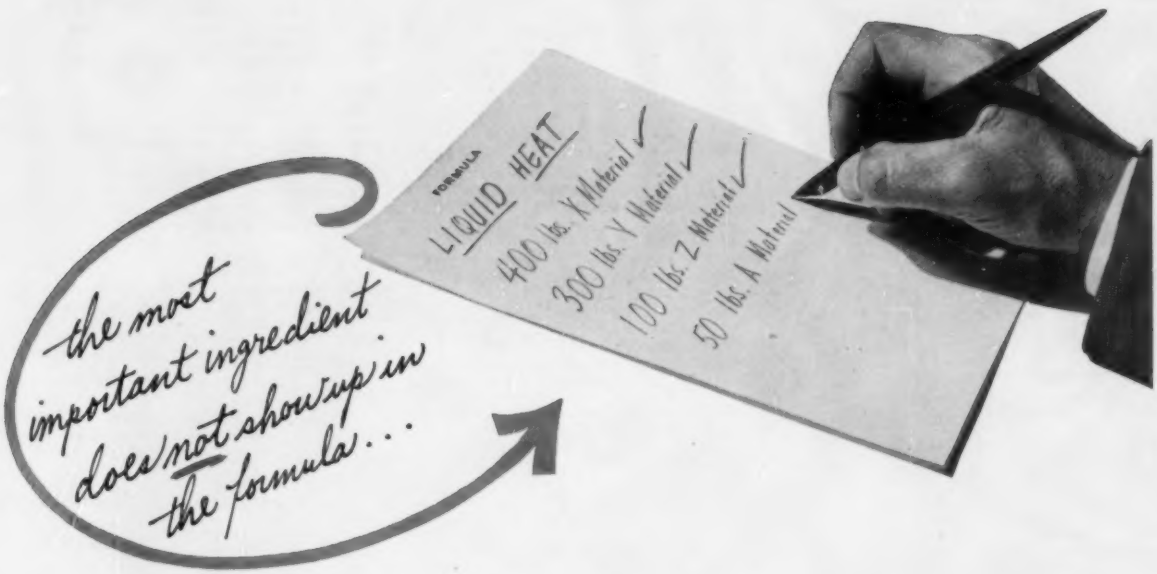
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688. Forgings
Bulletin on forge steelmaking, open die forging, machining, heat treating and finishing. *National Forge*

689. Forgings
94-page book on die blocks and heavy-duty forgings. 20 pages of tables. *A. Finkl & Sons*

690. Forgings
Chart on metallurgical problems encountered in closed die forgings and how they can be solved. *Drop Forging Assoc.*

691. Forgings
Data on forging products and electrically welded composite die sections. *Composite Forgings, Inc.*

692. Formed Shapes
26-page catalog No. 1555 contains drawings and dimensions of more than 100 shapes. *Roll Formed Products Co.*

693. Forming Stainless
24-page booklet describes processes applicable, contouring shaped sections, drawing, spinning, upsetting, hot forming and forming tubing. *Crucible Steel*

694. Foundry Equipment
4-page booklet on automatic casting machine tells how it works and type of casting which may be produced. *Carl Wessel*

695. Furnace
Description of new spheroidizing furnace installed at Budd Co., in Metal Minutes, Nov. 1956. *Sunbeam Corp.*

696. Furnace Belts
42-page booklet on alloy steel belts for continuous high-temperature furnaces. Belt selection guide. *Wickwire Spencer Steel Div.*

697. Furnaces
Bulletin 435 on furnaces for tool room, experimental or small batch production. Gas, oil, electric. Muffle or direct heated. *W. S. Rockwell*

698. Furnaces
Folder describes complete set up for heat treatment of small tools, including draw furnace, quench tank and high temperature furnace. *Waltz Furnace*

699. Furnaces
6-page folder on gas-fired, oil-fired and electric furnaces. Typical installations. *Electric Furnace*

700. Furnaces
44-page Catalog 112 features furnaces for hardening, tempering, carbonitriding, forge heating, sintering, annealing and tool heat treating. Also atmosphere generators and ammonia dissociators. *C. I. Hayes*

701. Furnaces
Monthly bulletin on used equipment. *Metal Treating Equipment Exchange*

702. Furnaces
Bulletin on electric heat treating furnaces describes five series and accessories. *Lucifer Furnaces*

703. Furnaces
New catalog on standard and special furnaces and ovens to 3000° F. *L & L Mfg.*

704. Furnaces
High-temperature furnaces for temperatures up to 2000° F. are described in bulletin. *Carl-Mayer Corp.*

705. Furnaces
New bulletin on graphite tube furnaces for temperatures to 5000° F. Operating limitations, auxiliary and control equipment. *Harper Electric*

706. Furnaces
32-page catalog of industrial equipment includes furnaces and furnace accessories, special valves, mechanical equipment, materials handling equipment. *Salem-Brosius*

707. Furnaces
12-page reprint on design, construction and application of chain belt conveyor furnaces. *Electric Furnace Co.*

708. Gas Analysis
Bulletin No. 306 on gas analysis kits for on-the-job determinations of carbon dioxide or oxygen in flue gases, furnace atmospheres and other gas mixtures. *Burrell*

709. Gas Analyzer
Product Specification E65-3 on combustibles analyzer for atmosphere control. *Bailey Meter*

710. Gas Generator
Bulletin 753R on endothermic generator gives construction, principles of operation, special features. *Hevi-Duty*

711. Gold Plating
Folder on salts for bright gold plating. Equipment needed. *Sel-Rex*

712. Graphite Electrodes
Vest-pocket notebook containing 90 pages of information on electric furnace electrodes and other carbon products. *Great Lakes Carbon Corp.*

713. Graphite Refractories
New 24-page booklet on graphite base refractories. Applications in iron and steel foundries and steel mills. *Mexico Refractories Co.*

714. Hardening Furnaces
Bulletin Sc-164 on hardening and drawing furnaces describes work handling mechanisms and heating methods. Chart of Rockwell hardness vs. drawing temperature for 40 steels. *Surface Comb.*

715. Hardness Tester
20-page book on hardness testing by Rockwell method. *Clark Instrument*

716. Hardness Tester
Data on hardness testing scleroscope with equivalent Brinell and Rockwell C numbers. *Shore Instrument*

717. Hardness Tester
Bulletin on Brinell tester with test head for deep and offset testing. *King Tester*

718. Hardness Tester
4-page bulletin on tester for both superficial and regular hardness testing. *Torsion Balance Co.*

719. Hardness Testers
Folder on portable hardness testers for testing of various sizes, shapes and types of metal. *Newage International*

720. Hardness Testing
Bulletins on Wolpert-Gries machines for standard Rockwell tests. Motorized reflex type for Brinell tests. *Gries Industries*

721. Hardness Testing
8-page catalog B-953 on principles and standards of Brinell hardness testing, and types of machines. *Steel City Testing Machines*

722. Heat Treating
Bulletin describes baskets, crates, trays, furnace parts for heat treating. *Stanwood*

723. Heat Treating
Data sheets and curves on hardenability, showing how to determine critical hardness, cooling rates to obtain critical hardness, from Jominy data. *Swift Industrial Chemical*

724. Heat Treating
Loose leaf data sheets on heat treating

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High-melting, long-lasting ALUNDUM cement is just one of many Norton ℞'s — refractories *engineered and prescribed* for longer, lower cost service across the range of furnace applications. Others include CRYSTOLON*, MAGNORITE*, and FUSED STABILIZED ZIRCONIA.

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oils, salts, carburizing compounds. *Park Chemical*

725. Heat Treating

16-page book on heat treating and pickling or stainless steels. Annealing, hardening and tempering temperatures and resulting properties. *Crucible Steel*

726. Heat Treating Ammonia

24-page "Guide for Use of Anhydrous Ammonia" describes heat treating and other metallurgical uses. *Nitrogen Div.*

727. Heat Treating Belts

Catalog of conveyor belts and data for their design, application and selection. *Ashworth Bros.*

728. Heat Treating Fixtures

12-page bulletin on wire mesh baskets for heat treating and plating. *Wiretex*

729. Heat Treating Fixtures

24-page catalog on heat and corrosion-resistant equipment for heat treating and chemical processing. 30 classifications of equipment. *Pressed Steel*

730. Heat Treating Fixtures

Folder on carburizing boxes, trays, heat treat fixtures and baskets. *Misco*

731. Heat Treating Fixtures

32-page Catalog G-10 covers heat and corrosion resistant fabricated alloy products. Includes furnace muffles, trays, fixtures, retorts, pit-type furnace equipment, salt bath equipment, pickling and plating equipment. *Rolock, Inc.*

732. Heat Treatment

Precision heat treatment of jet aircraft parts in Metal Minutes No. 5, Vol. 15. *Sunbeam Corp.*

733. Heaters

Bulletin on immersion heaters for electroplating solutions. *Glo-Quartz*

734. Heating Elements

24-page Bulletin H on electric heating elements. Includes extensive tabular data on physical and electrical specifications for various sizes. *Globar Div.*

735. High-Speed Steel

Folder on Electrite Double Six M-2 XL tungsten-molybdenum high speed steel containing alloy sulphides for improved machinability and increased tool life. *Latrobe Steel Co.*

736. High-Strength Steel

48-page book on T-1 steel, its properties and applications. *U.S. Steel*

737. High-Strength Steel

26-page booklet on properties, uses, applications of high-tensile low-alloy steel. *Jones & Laughlin*

738. High-Temperature Alloys

Booklet "Keep Operating Costs Down When Temperatures Go Up." *International Nickel*

739. High-Temperature Alloys

28-page reprint on materials for high-temperature, high-pressure main steam piping. Bibliography. *Tempil® Corp.*

740. High-Temperature Belts

Bulletin T-241 on belts on high-temperature alloy for heat treat furnaces. *Electro-Alloys*

741. High-Temperature Lubrication

Bulletin 423 on colloidal graphite and molybdenum disulfide dispersions and their use for high-temperature lubrication. Case histories. *Acheson Colloids*

742. High-Vacuum Furnaces

12-page brochure No. 790 on vacuum furnaces for melting and casting titanium, zirconium, germanium, copper, iron and steel. Also furnaces for annealing, hardening, brazing. *F. J. Stokes*

743. Immersion Heating

4-page bulletin H-11 on correct selection, sizing and installation of equipment for immersion heating. *Eclipse Fuel Eng.*

744. Impact Testing

Bulletin on machine for Izod, Charpy and tension testing. *Riehle*

745. Indicators and Recorders

New data sheet ND46-27 (100) on electronic speed indicators and recorders. *Leeds & Northrup*

746. Induction Furnace

4-page folder on combination induction melting and holding furnace and automatic pouring unit. *Ajax Engineering*

747. Induction Heaters

8-page bulletin on new electronic induction heaters. Specifications for four models. Special features. *General Electric*

748. Induction Heating

8-page bulletin on high-frequency motor-generator sets for induction heating. *Ohio Crankshaft*

749. Induction Heating

8-page bulletin on low and high frequency equipment. Charts on depth of hardness, frequency selection chart. *Magnethermic Corp.*

750. Induction Heating

12-page booklet B-6519 on equipment for induction heating for forging, hardening, annealing and metal joining. *Westinghouse Electric*

751. Induction Heating

Folder 15C8053A gives advantages of induction heating and specifications and dimensions of induction heater. *Allis-Chalmers*

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752. Induction Melting
Bulletin 70 on furnace. Controls, designs. *Inductotherm Corp.*

753. Industrial Heating
Booklet on process heating operations for light metals. *Michigan Oven Co.*

754. Inoculant
New 96-page booklet on SMZ alloy, an inoculant for cast iron. Metallurgical aspects of inoculation. How to inoculate irons. *Electro Metallurgical Co.*

755. Inspection
New 16-page booklet on magnetic particle inspection. Equipment, uses, kinds of defects that can be found. *Magnaflux*

756. Inspection
Descriptive information and instructions for new inspection process to detect surface flaws on all ferrous and nonferrous metals. *Zaco Laboratories*

757. Instruments
New data sheet ND46-51 (100) on instruments for millivoltage measurements. *Leeds & Northrup*

758. Insulators
Bulletin P1-55 on insulators and insulating tubing. *McDanel Refractory Porcelain*

759. Laboratory Supplies
Instruments and apparatus for control, research, development laboratories. *Harshaw Scientific*

760. Lubricant
Bulletin 103A on fringe area lubrication with molybdenum disulfide lubricants for extreme bearing pressures and all temperatures. *Alpha Molykote*

761. Lubricant
Literature on anti-seize molybdenum disulfide lubricant. *Bel-Ray*

762. Lubricants
8-page booklet on colloidal greases, forging compounds, hydraulic concentrate and others. *Grafo Colloids*

763. Machining Costs
12-page "Relation of Machining Time to Material Cost". Comparative machinability costs per ton for eleven steels. *La Salle Steel*

764. Magnesium
42-page booklet on wrought forms of magnesium. Includes 31 tables. *White Metal Rolling & Stamping*

765. Malleable Castings
Continuing series of information bulletins covering latest techniques and practices in modern malleable casting. *Malleable Founders' Society*

766. Malleable Iron
New 24-page booklet on strength and machinability of malleable iron. Metallurgical characteristics of pearlitic malleable. *Albion Malleable Iron Co.*

767. Manganese
9-page article on electromanganese. Manufacturing procedures, product characteristics, uses. In Foote Prints, V. 28, No. 2. *Foote Mineral Co.*

768. Master Alloys
24-page pocket bulletin on high alloy materials also includes metric equivalents tables, element melting points, temperature conversion tables. *Alloy Metal Products, Inc.*

769. Mechanical Cleaning
Booklet on how brushes are used for cleaning welds, stainless sheets, hot cast iron, automotive parts, brass fixtures. *Brush Div., Pittsburgh Plate Glass*

770. Metal Cutting
64-page catalog No. 30 gives prices and describes complete line of rotary files, burrs, metalworking saws and other products. *Martindale Electric*

771. Metal Laminates
8-page bulletin on metals used, advantages, applications, properties. *Bridgeport Brass*

772. Microscopes
8-page booklet No. 5 on research microscopes, stages, illuminators and other accessories. *American Optical*

773. Microscopes
40-page catalog on metallographs, metallurgical, toolmakers, stereoscopic, polarizing, phase and other microscopes. *Unitron Instrument Div., United Scientific*

774. Microscopes
22-page catalog describes microscopes featuring ball bearings and rollers throughout the focusing system and a low-position fine adjustment, providing comfortable operation. *Bausch & Lomb*

775. Molybdenum
72-page book gives data on unalloyed molybdenum and four arc-cast alloys. Several pages of references. *Climax Molybdenum*

776. Nickel Alloys
Wall chart gives engineering properties of nickel alloy wire, rod and strip. Includes Monel, Inconel, Incoloy and nickel-clad copper. *Alloy Metal Wire Co.*

777. Nitrogen Generator
New 6-page bulletin No. I-100 gives flow diagram and explains operation. *C. M. Kemp Mfg. Co.*

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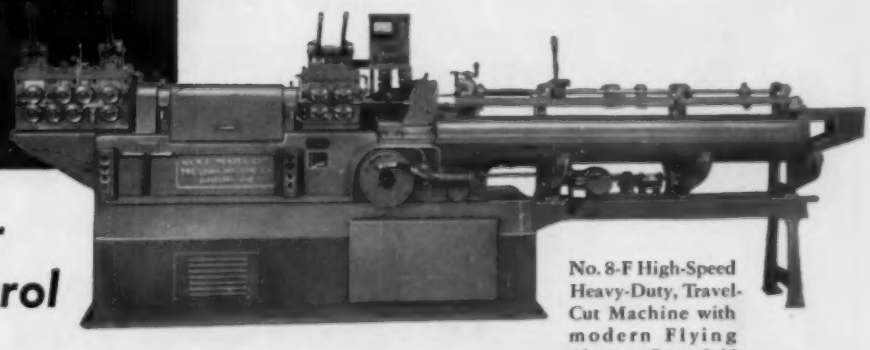

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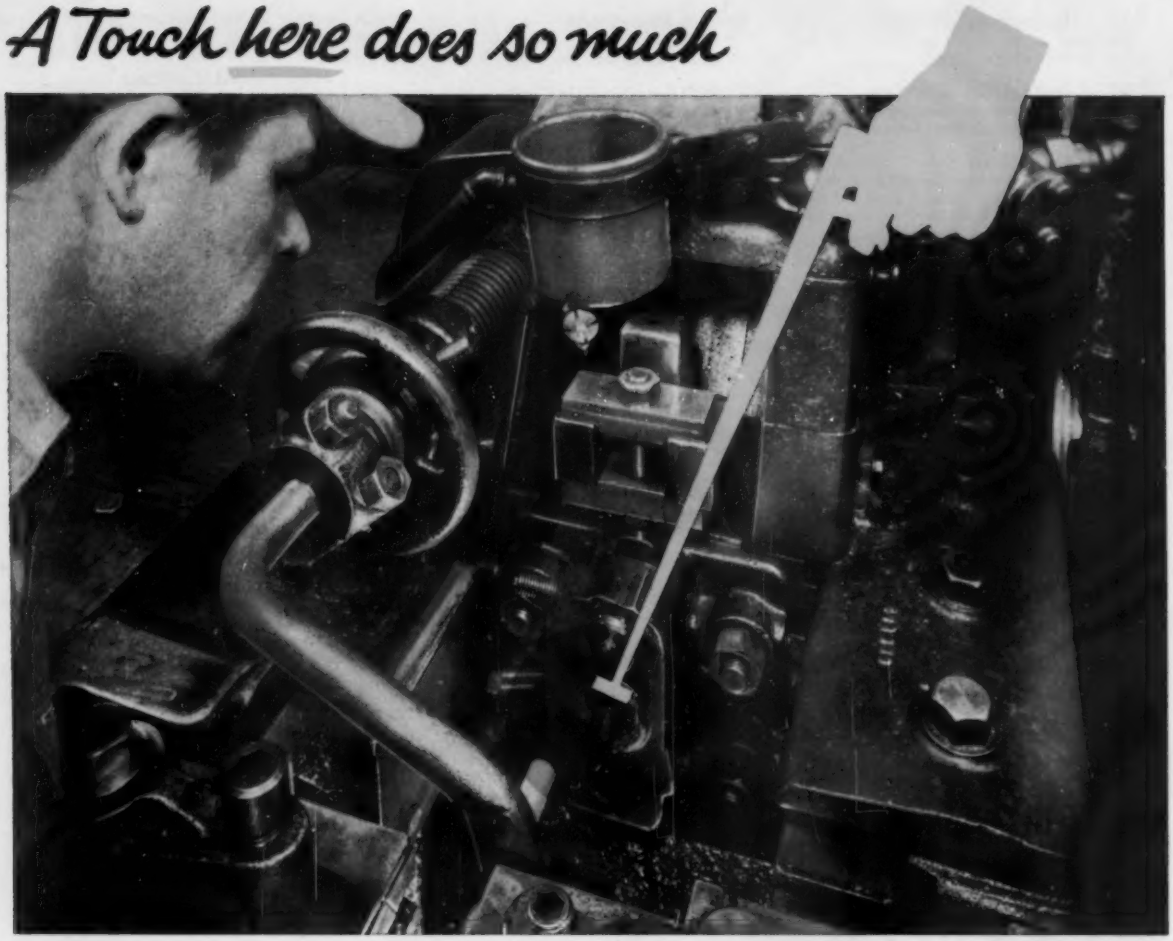

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778. Nondestructive Inspection
8-page bulletin on use of ultrasonic Reflectoscope describes principles of ultrasonic inspection and its uses. *Sperry Products*

779. Nondestructive Testing
8-page bulletin on equipment for nondestructive testing of bars, rods, tubing. *Magnetic Analysis*

780. Nondestructive Testing
Data on new nondestructive thickness tester. *Unit Process Assemblies*

781. Nonferrous Forgings
34-page booklet on brass, bronze and aluminum forgings. How they are made, composition of alloys, tolerances. *Mueller Brass.*

782. Nonflammable Rust Preventive
Bulletin on rust preventive compound which is water soluble, nontoxic and nonflammable. *Production Specialties*

783. Oil Quenching
8-page brochure tells in detail how carbon steel often can replace alloy steel when additive is used in the quenching oil. *Aldridge Industrial Oils*

784. Ovens
Bulletin 10-S on cabinet ovens describes those for use with gas, electric and steam heat for temperatures to 600° F. *Young Brothers*

785. Painting
Brochure on airless spray painting. *Bede Products*

786. Patterned Metal
16-page bulletin B-35 on embossed sheet and strip in copper, brass, bronze and nickel silver. *American Brass Co.*

787. Pickling Baskets
12-page bulletin on mechanical picklers, crates, baskets, chain and accessories. *Youngstown Welding & Eng'g*

788. Pickling Baskets
Data on baskets for degreasing, pickling, anodizing and plating. *Jelliff*

789. Pipe
4-page bulletin on Yoloy continuous weld pipe. Chemistry, properties, corrosion resistance. *Youngstown Sheet & Tube*

790. Plating
New 8-page brochure on test equipment for plating baths. Controls, anodes, cathodes, agitators, rectifiers described. *R. O. Hull & Co.*

791. Potentiometer
New 8-page bulletin on portable potentiometer with interchangeable direct-reading scales. *Technique Associates*

792. Powder Press
Dorst automatic press for powdered metal is described in bulletin. Pressure ram stroke and other specifications. *Arnhold Ceramics*

793. Powdered Iron
Properties of Plast/Iron with and without copper. *Plastic Metals Div.*

794. Powdered Metals
Booklet on design, properties, production and application of brass and other nonferrous powder parts. 24 case histories. *New Jersey Zinc*

795. Precision Casting
12-page book on alloy selection and design for investment casting. *Arwood Precision Casting*

796. Precision Casting
8-page bulletin on investment castings of various ferrous and nonferrous alloys. *Engineered Precision Casting*

797. Presses
8-page bulletin on new straight side crank-type press. Standard specifications. *Hamilton Div., Baldwin-Lima-Hamilton*

798. Pure Metals
Data sheets on vacuum melted cobalt, copper, iron and nickel. *Vacuum Metals*

799. Pyrometer
Catalog 85 on micro-optical pyrometer gives outstanding features, operating procedure and applications. *Pyrometer Instrument*

800. Pyrometer Supplies
56-page bulletin P1238 on thermocouples and pyrometer accessories. Engineering data on selection and installation. *Bristol*

801. Quench Agitation
Information on mixers and agitators, including units applicable to industrial quenching equipment. *Mixing Equipment*

802. Quenching
Catalog on two small self-contained quenching units. *Bell & Gossett*

803. Quenching
Bulletin No. 11 on quenching oil also discusses advantages of quench agitation. *Sun Oil Co.*

804. Quenching Oil
10-page book on new oils for the quenching process gives results on hot wire quench test and in plant operation. *Sinclair Refining Co.*

805. Radiant Heat
Bulletin HD-740R describes and illustrates construction of radiant heat elements and shows how they are installed in furnaces. *Hevi Duty*

806. Rare Earths
12-page handbook on rare earth chemicals, thorium. Applications of rare earths. *Heavy Minerals Co.*

807. Recirculating Furnace
Bulletin on continuous-type recirculating furnace shows design of furnace, its operation and advantages. *Industrial Heating Equipment*

808. Refractories
24-page bulletin on physical and chemical properties of super refractories. Applications. *Refractories Div., Carborundum*

809. Refractories
12-page brochure on products for casting special refractory shapes and for gunning and troweling applications, for service to 3000° F. *Johns-Manville*

810. Refractory Coating
Data on aluminum oxide and silicon carbide coating which may be sprayed on. *Norton Co.*

811. Refrigerated Bath
Bulletin on refrigerated baths, visible and constant temperature models. Construction, applications. *Wilkens-Anderson*

812. Resistance Welder
8-page bulletin 3-513 on press welder describes styles, welding heads, controls and accessories. *Taylor-Winfield Corp.*

813. Rhodium Plating
Data on properties, thicknesses required, costs, operation, applications. *Technic*

814. Rolling Mills
Catalog on line of machines for rolling ferrous and nonferrous metals gives descriptions and lubrication and maintenance instructions. *Fenn Mfg. Co.*

815. Rust Prevention
Data sheets describe solvent type and emulsifiable type rust resisting compounds. *Swift Industrial Chemical*

(Continued on page 48-a)

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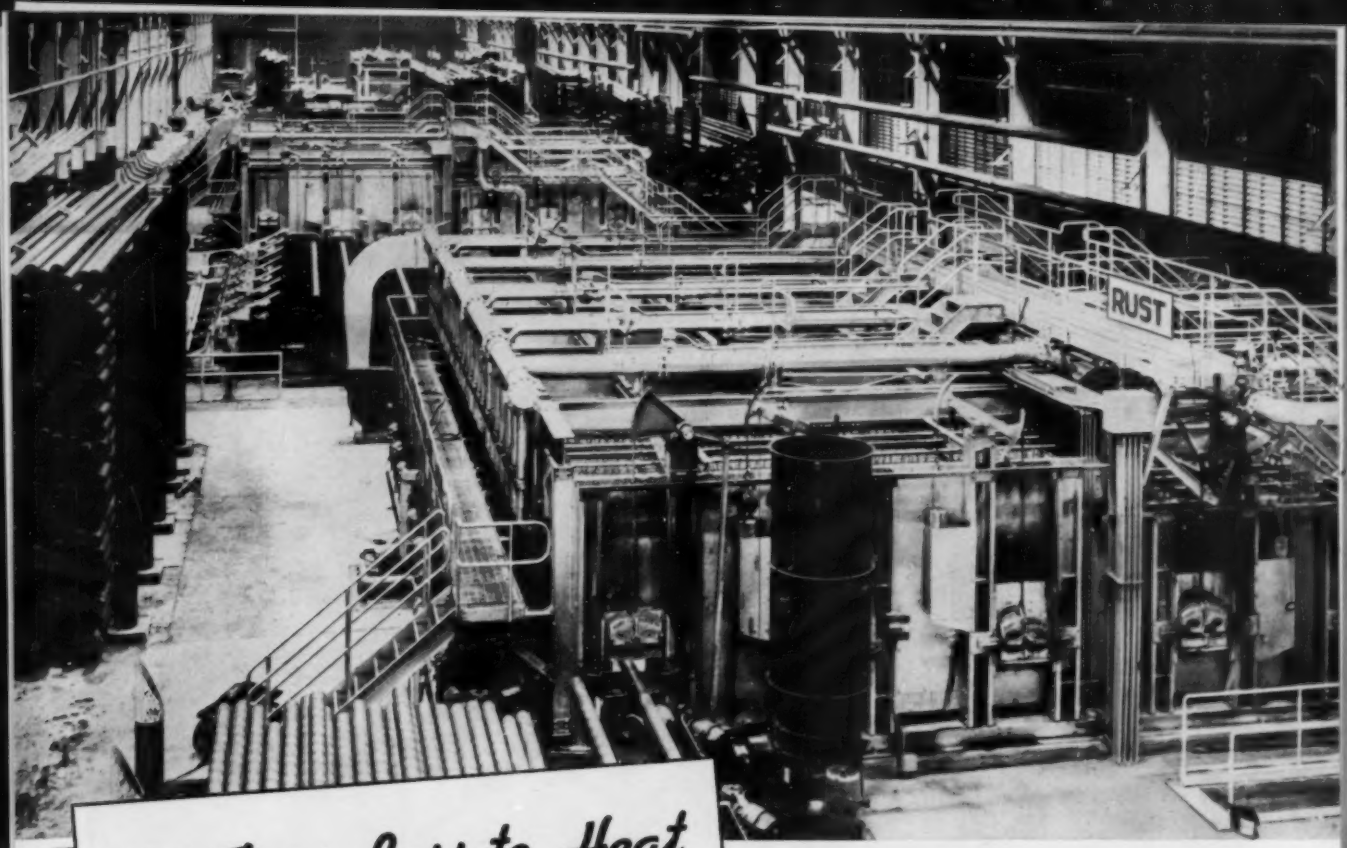


116 Tons Less to Heat in this roof

because of B&W Insulating Firebrick suspended construction

Here's another case where light weight means lower cost. The roof of this walking beam furnace is 2,320 square feet. B&W Insulating Firebrick suspended construction for a 9-inch roof weighs about 30 lbs per square foot, including the weight of rods, hangers, pipe, brick and mortar. This is approximately 100 lbs per square foot less than an arch constructed of heavy firebrick plus insulation having the same heat flow. *This saving means the B&W IFB roof is 116 tons lighter.*

The new walking beam furnace (shown in photograph above) was designed and constructed by Rust Furnace Company for Jones & Laughlin Steel Corporation. Seamless pipe is conveyed into the furnace, moves slowly from left to right on walking beam rails designed and furnished by York-Gillespie Mfg. Co., and passes out the exit door.

Here are the money-saving benefits of B&W suspended construction:

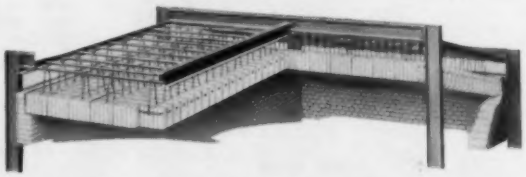
1. Supporting steel is less massive, far less costly. Commercial size steel can be used for roof suspension instead of special castings.

2. B&W Insulating Firebrick heat up and cool down faster. This means lower fuel costs, faster inspection.

3. Furnace temperatures can be changed quickly. When different steels call for different heating schedules, the furnace temperature can be adjusted in minutes instead of hours.

4. Installation costs are lower because these lightweight brick can be handled faster and easier than ordinary heavy firebrick.

For complete information on B&W IFB—the *lightest* weight insulating firebrick, write to B&W today or call your local Refractories Engineer.



This is a cross-sectional drawing of a typical suspended arch arrangement using B&W Insulating Firebrick. It can be used in flat or sloping roofs, nose arches and many other types of suspended furnace construction.

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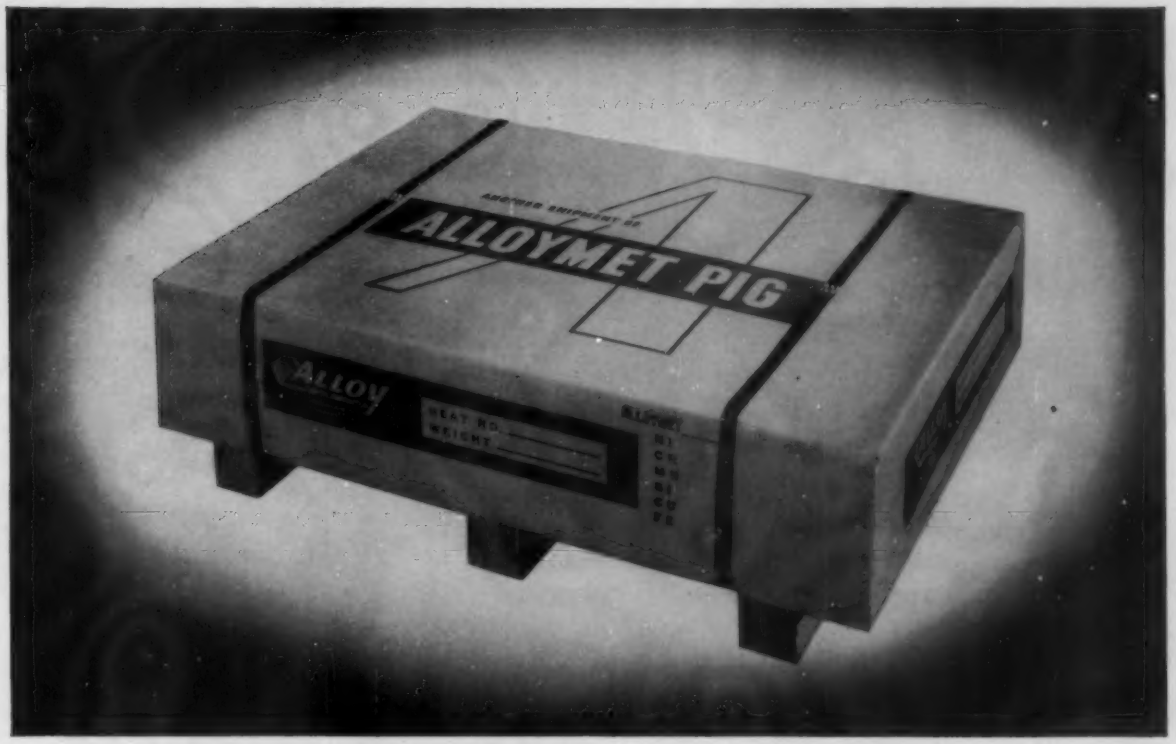

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26 nickel alloy pigs, each weighing about 50 pounds, travel inside this new palletized package. Weight and certified analysis are in plain view at all times. All fiberboard, it can go into the electric furnace "as is." It weighs only ¼ as much as a wooden pallet. Saves on transportation costs. Discourages pilferage. Speeds handling.

Users are already enthusiastic about this new nickel alloy package. Like the quality product it contains, it serves as a further example of the exacting care Alloy Metal Products, Inc., exercises in every phase of the production of alloy metals.

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(Continued from page 47)

816. Rust Prevention
72-page book on cleaning, preservation, and packaging of metals. Causes of corrosion. *E. F. Houghton*

817. Salt Bath Furnaces
Folder on salt bath furnaces, Type 701, gives advantages. *A. F. Holden*

818. Salt Baths
Reprints 161 and 162 on new advances in hot salt quenching and salt bath quenching of gears. *Ajax Electric*

819. Sawing
Data on bandsawing and bandfiling machine. Applications, description of machine. *S & S Machinery Co.*

820. Saws
Catalog C-55 describes 35 models of metal-cutting saws. *Armstrong-Blum*

821. Shear
Bulletin on bar and billet shear for rounds, squares, flats, billets and structurals, either hot or cold. *Hill Acme Co.*

822. Shot and Grit
Handy calculator has size data for SAE grades of shot and grit. *Pangborn*

823. Silver Brazing
48-page manual on all aspects of silver brazing applications and problems. *American Platinum Works*

824. Sintered Carbides
24-page booklet on the characteristics of the various grades, for research and design engineers. *Kennametal*

825. Slitting
76-page handbook on multiple rotary slitting lines. Design, selection and operation of slitters. Specifications and capacity tables. *Yoder Co.*

826. Smelting Equipment
48-page booklet 105 on equipment for smelting covers complete furnaces, electrodes and control equipment. *Pittsburgh Lectromelt*

827. Sodium
40-page booklet on handling metallic sodium gives typical sodium-using processes, equipment installation, recommendations for pumping and instrumentation. *U.S. Industrial Chemicals*

828. Spectrograph
24-page booklet on Echelle spectrographs. Advantages. Type of work produced. *Bausch & Lomb*

829. Spectrographic Supplies
24-page catalog on special pure materials and alloy standards, plates and films, graphite electrodes and powders. *Jarrell-Ash*

830. Spectrometry
12-page booklet on Hilger-Schwarz thermopiles for conversion of infra-red energy into electrical energy. *Jarrell-Ash*

831. Stainless Castings
List of standard designations and chemical composition ranges for heat and corrosion resistant cast alloys. *Alloy Casting Institute*

832. Stainless Fastenings
20-page catalog of stainless steel cap screws, nuts, washers, machine screws, sheet metal screws, set screws, pipe fittings and specialties. *Star Stainless Screw*

833. Stainless Steel
16-page booklet on Type 430 stainless gives physical properties and analysis, corrosion resistance, fabrication, application and care. *Washington Steel*

834. Stainless Steel
Processes for removing and preventing heat forming and heat treat scale on various alloy of stainless steel. *Turco Products*

835. Stainless Steel
12-page booklet on new AM 350 chromium-nickel-molybdenum stainless steel which is hardenable by subzero cooling or double aging. *Allegheny Ludlum*

836. Stainless Steel
Selector gives machinability, physical and mechanical properties, corrosion resistance of various grades of stainless steel. *Crucible Steel*

837. Stampings
16-page brochure on story of stamping. Handy tabular data. *Republic Steel*

838. Steel
Bulletins on hot work steel and Type 420 stainless give forging, annealing and hardening characteristics. *Firth Sterling*

839. Steel
256-page handbook lists sizes, weights, lengths, steels available, shapes. Data on mechanical properties, standard steel compositions, hardness numbers conversions. *Ryerson*

840. Steel 52100
Stock list on 52100 tubing, bars and ring forgings. *Peterson Steels*

841. Steel Castings
New summary of steel castings specifications recommended for commercial, railroad, federal and military use. Testing methods recommended. *Steel Founders' Society*

842. Steel Terms
32-page dictionary of terms used in the steel industry. 180 definitions. Equilibrium diagrams, tables and figures. *LaSalle Steel*

843. Steelmaking
Beautifully illustrated brochure on steelmaking, annealing, hot rolling, finishing. *Rotary Electric Steel*

844. Sub-Zero Treatment
12-page booklet on industrial chilling equipment for shrinking, testing and treating of metals. *Cincinnati Sub-Zero Products*

845. Temperature Conversion
Chart converts degrees Fahrenheit to Centrigrade and vice versa from —400 to 4000° and shows range of sensing elements. *Thermo Electric*

846. Temperature Conversion
16-page temperature conversion booklet and electromotive force of thermocouple alloys in absolute millivolts. *Wheelco*

847. Temperature Measuring
Bulletins on Tempilstiks and Tempilaq describe products and tell how to use them. *Tempil® Corp.*

848. Test Bars
18-page bulletin No. 168 on design of test bar patterns, production of test bars, testing procedures. *Federated Metals Div., American Smelting and Refining*

849. Testers
Data file lists 8 models, gives salient features, and illustrates preep testers and uses. *Arcweld Mfg.*

850. Testing Machines
8-page folder on Amsler machines for tests in tension, compression, torsion, shear, fatigue, bending and ductility. Bulletins on wear testing and testing of miniature samples. *Buehler*

851. Testing Machines
New 40-page bulletin on electomatic universal testing machines. Loading, weighing and indicating systems described. *Tinius Olsen Testing Machine*

852. Testing Machines
12-page catalog on ten testers including hardness, ductility, tensile, compression and transverse strength. *Detroit Testing Machine*

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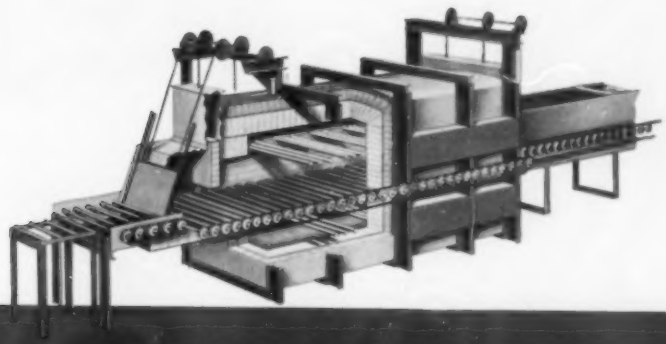
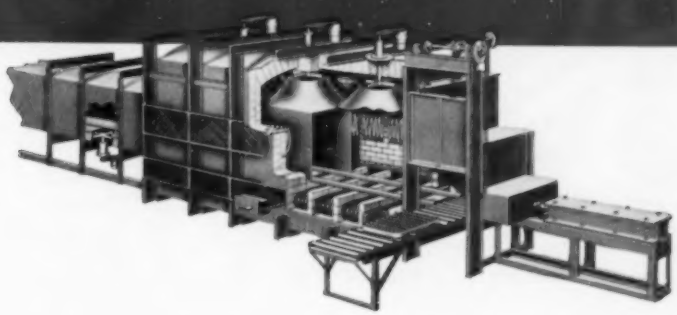


LET'S TALK ABOUT

the economy of electric heating



Low initial cost—simplified maintenance—efficient use of heat.

All these represent good reasons why electric heat treat furnaces are important considerations. For example, gas-fired and electrically-heated furnaces are frequently competitive; in fact, when total installation cost figures are considered, electric furnaces often have the price advantage.

Upkeep is reasonable, too, because properly designed and installed electric heating elements are so easy to maintain and adjust. Elements are quickly removed for repairs.

Electric heat is more efficiently used for applications in the high temperature range. There is a considerably smaller heat loss in the use of electricity than gas—shrinking the price spread between the two. To be specific, a thorough study must be made of all factors: local power and fuel costs, production demands, quality control standards, etc., before any final decision can be made of the type of heating to be used. Holcroft will help you—a good place to start is to send for our new book **Holcroft and the Electric Furnace.** It's yours without obligation. 5430

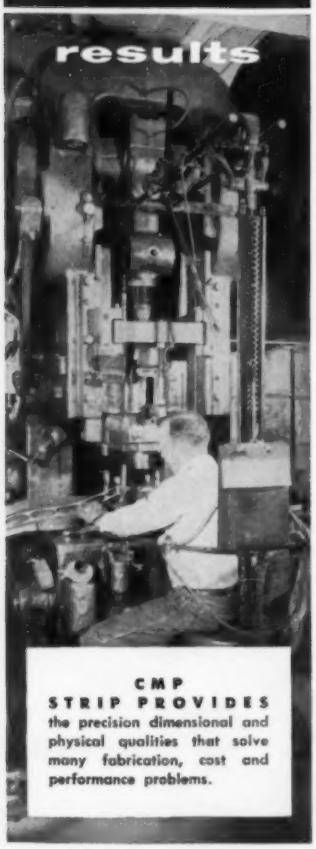
HOLCROFT AND COMPANY

6545 EPWORTH BOULEVARD • DETROIT 10, MICHIGAN

PRODUCTION HEAT TREAT FURNACES FOR EVERY PURPOSE

CHICAGO, ILL. • CLEVELAND, OHIO • HARTFORD, CONN. • HOUSTON, TEXAS • LOS ANGELES, CALIF. • PHILA., PA.
CANADA: Walker Metal Products, Ltd., Windsor, Ontario

pre-
planned
CMP
RESTRICTED SPECIFICATION
COLD ROLLED STRIP STEEL
boosts production, stops slow-downs, reduces die costs, meets feed and speed requirements of automatic equipment.


results
CMP
STRIP PROVIDES
the precision dimensional and physical qualities that solve many fabrication, cost and performance problems.

In estimating production costs, one of the items a metal fabricator takes into account is the cost of steel. As important as this is, it is sometimes good economics to pay more for steel, but pay less in the end for the fabricated part. The cost of down time on expensive forming equipment, the cost of idle labor, the cost of reprocessing defective parts, may well exceed the cost of the extras built into restricted specification steel, which will eliminate these unplanned-for costs.

CMP restricted specification cold rolled strip steel can be pre-planned to minimize production delays and produce for you the production cost you need. We will welcome the opportunity to explore with you the cost-saving potentials in your manufacturing processes which may be available to you by use of **CMP** restricted specification cold rolled strip steel.

CMP

WHERE YOU CAN GET
SPECIFIC SPECS
FOR
SPECIFIC JOBS

LOW CARBON, ELECTRO ZINC COATED,
HIGH CARBON, TEMPERED SPRING STEEL,
STAINLESS AND ALLOY

C·M·P

THE COLD METAL PRODUCTS CO.

GENERAL OFFICES: YOUNGSTOWN, OHIO
PLANTS: YOUNGTOWN, OHIO & INDIANAPOLIS, IND.
SALES OFFICES: New York • Cleveland • Chicago
Indianapolis • Detroit • Los Angeles • San Francisco

853. Thermocouple Alloys
20-page booklet on chromel-alumel alloys gives sizes, temperature-millivolt equivalents, standards, applications. *Hoskins Mfg.*

854. Thermocouple Insulators
New Bulletin No. 300-56 on complete line of thermocouple insulators. Dimensions, sizes, types of insulators. *Claud S. Gordon*

855. Thickness Control
New 12-page booklet on systems for automatic control of strip thickness of ferrous and nonferrous cold mills and of coatings. *Industrial Nucleonics Corp.*

856. Thickness Gage
Folder on pocket-size gage. How to use it. *Ferro Corp.*

857. Tin
20-page bulletin on importance of tin to the American industry. Applications in aircraft, chemical, container, electrical, electronic equipment and others. *Malayan Tin Bureau*

858. Titanium
8-page booklet on corrosion resistance of titanium. Table of ratings of titanium compared with stainless and aluminum in various mediums. *Mallory Sharon*

859. Titanium Alloy
12-page booklet on C-120AV titanium alloy. Physical properties, elevated-temperature properties, creep, fatigue, welding, machining, heat treatment. *Rem-Cru Titanium*

860. Titanium and Zirconium
16-page bulletin, "The Hydrimet Process", on titanium and zirconium metals and hydrides, and other metallurgical hydrides. *Metal Hydrides*

861. Titanium Carbide
29-page pocket-sized book reviews methods of manufacture, properties, uses. Bibliography. *Titanium Alloy Mfg. Div.*

862. Tool Steel
Wall chart showing more than 300 varieties of tool steel with trade name of manufacturers. *Vulcan Crucible Steel*

863. Tool Steel
44-page book on tool steels for the nonmetallurgist explains the six basic kinds of tool steel and their heat treatment. *Crucible Steel*

864. Tool Steel Failures
124-page book, "Tool Steel Trouble Shooter", analyzes 107 tool failures and assigns causes as among tool design faults, tool steel faults, improper heat treatment, mechanical and operational factors. *Bethlehem Steel*

865. Tool Steels
Bulletin on tool steels, hot work specialty steels, bar stock, billet, sand casting, drill rod, flat ground stock and tool bits. *Darwin & Milner, Inc.*

866. Tukon Tester
12-page bulletin DH-328 on Tukon micro and macro hardness testers. *Wilson Mech. Inst.*

867. Ultrasonic Cleaning
Folder on Sonogen ultrasonic generator for metal cleaning. *Branson*

868. Ultrasonic Testing
Data folder describes instruments using ultrasonics for various tests—immerscope, "B" scan and flaw recorder. *Curtiss-Wright*

869. Ultrasonics
Bulletin GEA-6239 on ultrasonic power generators for industrial cleaning equipment. *General Electric*

870. Ultrasonics
New bulletin MW-103 on use of ultrasonics in degreasing, electroplating, drilling, and grinding operations. *Acoustica Associates*

871. Vacuum Alloys
Folder on vacuum melted cobalt, ferrous and nickel-base alloys. Quality control. *Cannon-Muskegon Corp.*

872. Vacuum Furnaces
Articles on commercial vacuum furnaces for metals and alloys and some aspects of vacuum melted metals. *National Research*

873. Vacuum Furnaces
Bulletins P8-20 and P4-28 on vacuum arc melting furnaces and pumps. *Consolidated Electrodynamics*

874. Vacuum Metallizing
8-page catalog 551 on production and experimental-type metallizing units. *High Vacuum Equipment Corp.*

875. Vacuum Metals
21-page report on vacuum melted metals discusses equipment, properties of metals and their applications. *Ajax Electrothermic Corp.*

876. Vacuum Pumps
New 52-page catalog No. 425 on high vacuum pumps contains formulas and tabular data. *Kinney Mfg.*

877. Welding
Data on welding positioners from 500 to 100,000 lb. capacity. *Harnischfeger*

878. Welding Copper
24-page booklet on oxyacetylene, carbon-arc and metal-arc welding techniques for copper and copper alloys. *Revere*

879. Welding Electrodes
28-page bulletin RW-10 on resistance welding electrodes and accessories. Applications, specifications and dimensions. *Ampco*

880. Welding Equipment
Catalog on Cadweld process and arc-welding accessories. *Erico Products*

881. Welding Stainless
8-page Bulletin GET-1955 gives arc-welding practices for stainless steels. *General Electric*

882. Wire
New 120-page handbook lists 100 types of steel wire. Size ranges, weights, tensile strength and chemical composition for each type. 16 pages of tables and hardness conversion chart. *Pittsburgh Steel Co.*

883. Wire Cloth
How woven conveyor belts help in manufacture of springs in "Cambridge Wire," No. 4, 1956. *Cambridge Wire Cloth*

884. Wire Straightening
20-page brochure on wire straightening and cutting machines, wire reels, chamfering and deburring machines. New air clutch described. *Lewis Machine Co.*

885. X-Ray
12-page bulletin on gamma radiography tells how to select the source, equipment, techniques and fundamentals of gamma radiation. *Picker X-Ray*

886. X-Ray Equipment
28-page booklet on products for industrial radiography gives exposure and processing data for various films used. *DuPont*

887. X-Ray Equipment
12-page booklet on 250-kv. constant potential X-ray equipment for internal inspection. Advantages, design features. *Westinghouse Electric*

888. X-Ray Supplies
Bulletin on X-ray films and chemicals for radiography. *Ansco*

MARCH, 1957

597	622	647	672	697	722	747	772	797	822	847	872
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607	632	657	682	707	732	757	782	807	832	857	882
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609	634	659	684	709	734	759	784	809	834	859	884
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616	641	666	691	716	741	766	791	816	841	866	
617	642	667	692	717	742	767	792	817	842	867	
618	643	668	693	718	743	768	793	818	843	868	
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621	646	671	696	721	746	771	796	821	846	871	

METAL PROGRESS,

7301 Euclid Avenue, Cleveland 3, Ohio

Please have literature circled at the left sent to me.

Name _____

Title _____

Company _____

Address _____

City and State _____

Postcards must be mailed prior to June 1, 1957. Students should write direct to manufacturers.

by Carl F. Joseph
Technical Director

CENTRAL FOUNDRY DIVISION
GENERAL MOTORS
CORPORATION

.....The metallurgy of strength and

The secret of a stronger iron casting lies in the composition, the melting and the heat-treating processes. Perhaps I should use some other word than "secret," because the fact is well known today, but in 1925, when we started our search for a stronger iron, the principle was well known only in respect to steel.

Our research led us to think that heat-treating could improve iron as well. After considerable experimentation, we learned how to arrest the malleablizing process to produce an improved pearlitic malleable iron . . . an iron that compares favorably with the properties of a good grade forged steel. It is from the words "Arrested Malleable iron with Steel-like characteristics" that the name "ArmaSteel" was coined.

The raw materials and melting process for ArmaSteel are very similar to those of our malleable iron . . . the major difference being in the heat-treat cycle. In the cupola, we melt steel scrap, ferrosilicon, and remelt. We add .0025% boron to the charge to assist in breaking down carbides during malleablizing.

Next, the molten iron is tapped into a forehearth where it is desulphurized with soda ash. This removes small particles of slag and impurities, thus improving machinability of the casting. After refining in an electric furnace, the iron is tapped into ladles.

To improve the physical properties on certain castings, .007% bismuth is added as a ladle inoculant: this stabilizes the carbides during the initial freezing of the metal. On heavy castings such as the Pontiac crankshaft, up to .02% bismuth is added. This bismuth-boron combination is a new development.

I mentioned before that the heat-treating of ArmaSteel greatly affected its properties. Actually, we use several different heat-treatments to produce the several ranges of ArmaSteel. All are alike during the malleablizing cycle, where the massive carbides are eliminated. Malleablizing requires about 20 hours: the castings are held at 1750°F. for 10 hours, and near the end of the cycle are dropped to 1650°F., after which they are air-quenched. Brinell hardness at this point is around 300.

Tempering brings the Brinell hardness down to customer's specifications. We produce two standard Brinell ranges of air-quenched and tempered ArmaSteel . . . BHN 197 to 241 (3.9-4.3 mm.), and 163 to 207 (4.2-4.7 mm.). The castings are tempered in a recirculating furnace. The harder material is in the furnace for a total of six hours and forty minutes, and is held at heat for three and one half to four hours at 1270° to 1290°F. The softer material uses the same time cycle but higher heat . . . from 1320° to 1340°F.

For automobile crankshafts, a special hardness range is used. The ArmaSteel is air-quenched and tempered, but the tempering is for six hours at 1200°F., which produces a harder material (BHN 217 to 269).

Two other types of ArmaSteel are produced by reheating the air-quenched castings to 1600°, holding at heat for thirty minutes, then oil-quenching. These are then tempered for three and one half hours at 1170° to 1190°F. BHN is 241 to 260 (3.7-3.9 mm.) and 269 to 302 (3.5-3.7 mm.).

I've gone into detail on heat-treating because it has such a great effect on mechanical properties. Tempering directly controls the amount of combined carbon in the matrix, and this in turn dictates how hard and strong the ArmaSteel will be . . . the higher the combined carbon, the stronger, harder, and less ductile the casting. Thus, the engineer can choose the combination of properties best suited to his application. I can best explain the results of this careful heat-treatment by giving you a brief list of the mechanical properties of ArmaSteel.

1. *Machinability* . . . Because of the carbon nodules in the pearlite matrix, the machinability of ArmaSteel is generally from 10 to 30 percent better than that of steel forgings of the same Brinell. Improvements of up to ten times longer tool life and three times more pieces per machine have been shown.

2. *Selective Hardening* . . . ArmaSteel responds readily to localized hardening, either by flame or induction methods. A minimum of Rockwell "C" 50 is obtainable on such parts as shifter yokes, rocker arms, and gears. Some applications use the lead immersion or hot salt bath methods, followed by an oil-quench.

3. *Bearing Properties* . . . ArmaSteel is such an efficient bearing material on a hardened steel shaft that bronze bushings are often eliminated. The automotive rocker arm illustrates this excellent non-seizing property in metal-to-metal wear.

4. *High Yield Ratio* . . . The oil-quenched and tempered ArmaSteel has a minimum yield strength of 80,000 psi and ultimate strength of 100,000 psi, making it ideal for highly stressed parts.

5. *Fine Machine Finish* . . . A mirror-like finish can be produced on ArmaSteel. Diesel pistons are an application where this fine finish reduces friction wear to a minimum.

6. *Damping Characteristics* . . . In both small engines and in automotive engines, ArmaSteel crankshafts exhibit a fine damping capacity that aids quiet operation.

7. *Wear Resistance* . . . ArmaSteel withstands excessive wear under heavy loads at high speed.

8. *Fatigue Life* . . . ArmaSteel has good resistance to fatigue, giving maximum endurance and long life.

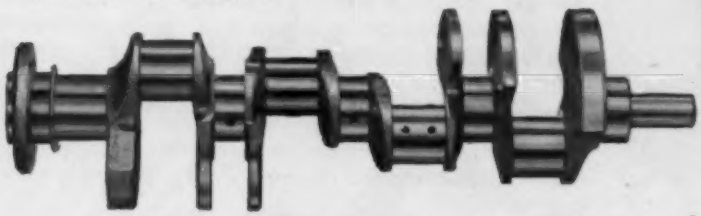
As countless and varied applications have proven, ArmaSteel is an outstanding engineering material. For information on how your product can benefit from this modern casting metal, write for our "ArmaSteel" catalog.

ARMASTEEL® from the standpoint of machinability

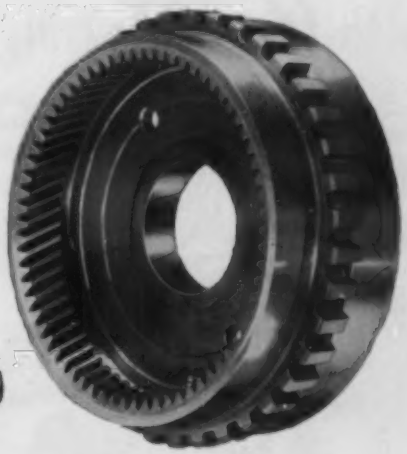
ArmaSteel small horsepower engine crankshafts provide good damping qualities and modest cost due to excellent machinability.

ArmaSteel's adaptability to localized hardening pays off especially well on these automotive rocker arms.

Universal joint yokes of ArmaSteel stand up under severe stresses to same extent as former SAE 1145 or 1151 forgings.



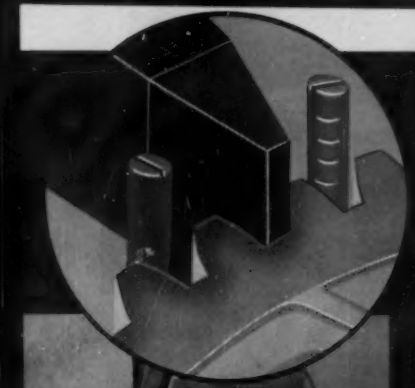
Pontiac's conversion to ArmaSteel Crankshafts doubled cutter life and speeded up by 50% the grinding of main journals.



Because of its excellent wear resistance, oil-quenched and tempered ArmaSteel with a Brinell of 241 to 269 has replaced an SAE steel forging for this automotive reverse internal gear.

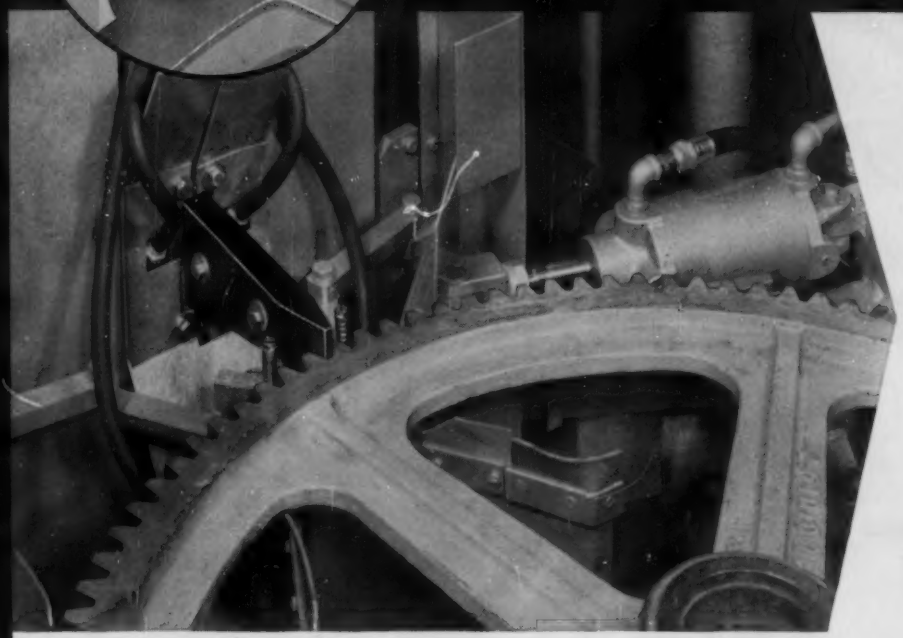
CENTRAL FOUNDRY DIVISION

GENERAL MOTORS CORPORATION • SAGINAW, MICHIGAN • DEPT. 19



LOOK TO THE ROOT

FOR IMPROVED GEAR PERFORMANCE



tooth by tooth Gear "Hardening"

with Magnethermic HIGH FREQUENCY Induction Scanning Equipment

Heat treating the critical root zone makes an appreciable difference in physical properties and fatigue strength.

With high frequency induction heating, the tooth can be full hard for maximum wear resistance. Large gears can be hardened with small capacity equipment.

Scanning eliminates the need for inductor change with varying gear face widths. Automatic controls, including indexing and quenching, result in a high production rate and uniform results.

This is one type of gear hardening. Size and production rate dictate to a great degree the type of equipment. Whatever your need in gear hardening or other heating applications, Magnethermic's experience with induction heating can be useful.

Prompt response to your inquiry — Magnethermic, Youngstown, Ohio.

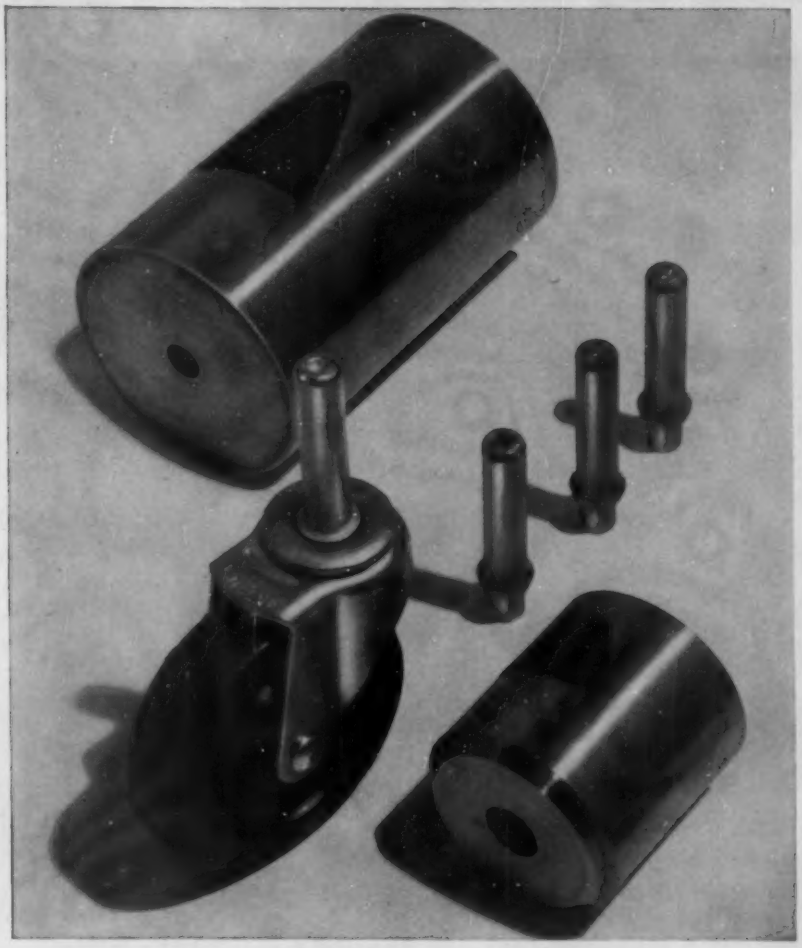
see MAGNETHERMIC for Induction Heating

INDUCTION HEATING EQUIPMENT

MAGNETHERMIC
corporation
3990 SIMON ROAD YOUNGSTOWN 7, OHIO

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.



Maker of Casters Gets Good Results with Water-Hardening Steel

The Bassick Company, Bridgeport, Conn., a leading manufacturer of casters, needed a good grade of tool steel for the dies and punches used in producing caster stems. They took the problem to Lindquist Steels, Inc., their local tool-steel distributor, who recommended Bethlehem W-1 Carbon Water-Hardening tool steel for cold-heading purposes. The performance of this grade, with its controlled hardenability, has been excellent.

The dies and punches, some of which are illustrated above, are hardened to about Rockwell C-60, and work on Bethlehem Cold-Heading Wire. They have proved economical, as their service life is approximately 100,000 pieces.

Bethlehem Carbon Water-Hardening tool steel has high shock-resistance because it is carefully controlled for hardenability. Besides, with its controlled carbon range, it has good resistance to wear, plus the toughness to withstand cold battering.

There may be one or more applications in your shop where Bethlehem Carbon Water-Hardening tool steel could be used to advantage. Why not talk it over with your Bethlehem tool steel distributor?

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Bend Tool Steels While They're Hot

The structure of machinery is such that parts are sometimes fabricated of steel which has been cold-bent to shape. However, when some of the components are made of tool steel, bending usually cannot be done at room temperature without causing breakage. Some degree of heating must therefore be employed.

For severe bending, such as bending to a small diameter, the tool steel is usually heated to the full forging temperature. Depending upon the grade, this may be 2000 F or higher. Moderate bending (curving into a shape similar to a leaf spring) can take place after heating to about 1300 F, being careful that the maximum temperature reached does not exceed the critical temperature. Very light bending operations (perhaps bending a shear blade to compensate for expected warpage in heat-treatment) can be accomplished at room temperature if a generous radius of curvature is used.

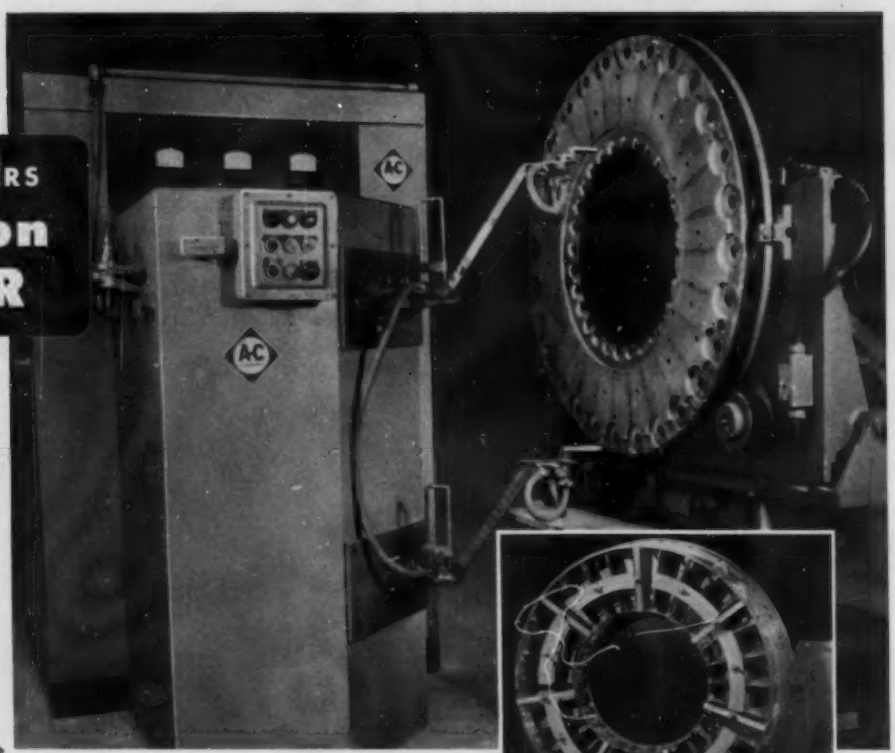
Making 36-lb Nut Behave

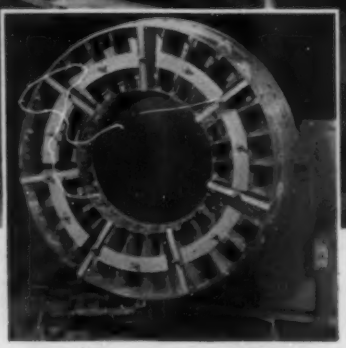
Here is a shaving die, made of Lehigh H tool steel, used in hot-broaching the sides of a 4¼-in. hexagon nut. Lehigh H is our special-purpose high-carbon, high-chromium grade of tool steel. Its excellent wear-resistance and red hardness make it an ideal steel for this application.

RHEEM MANUFACTURING COMPANY

Precision Brazes at Jet Speeds

ALLIS-CHALMERS
Induction HEATER





Each FACSIMILE Weldment of Vanes in Inlet Guide Assembly for J-57 Engine Completed in Seconds

Mr. Hi Frequency is Ready and Able to Help You, Too

If your job is one of brazing, soldering, hardening, annealing, or heating, it will pay you to get all the facts on induction heating. Contact your A-C representative or write Allis-Chalmers, Industrial Equipment Division, Milwaukee 1, Wisconsin.

UTILIZING an Allis-Chalmers 25-kw induction heater, and an *A-C designed work fixture*, Rheem has a brazing setup as streamlined as the jet planes they help build. Rheem's production speed is particularly significant in that it is accomplished in the face of stringent precision requirements, demanding accurately controlled localized heating. Close tolerances are a requirement. Yet the Allis-Chalmers induction heater, brazing at high speed, produces facsimile weldments — each as smooth and perfect as the next.

Specify A-C—Here's Why

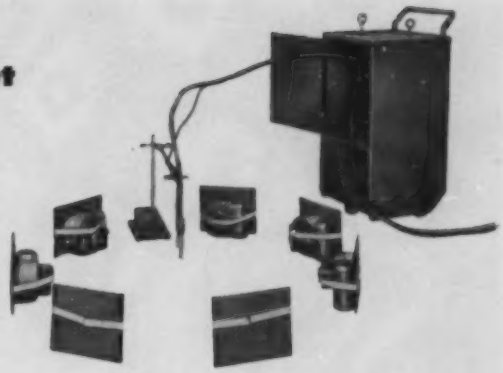
The use of high frequency power makes Allis-Chalmers induction heating as much as seven times faster than conventional heating methods. Properly designed work handling equipment also speeds production. An automatic timer and other controls, standard on Allis-Chalmers units, promote precision operation. Allis-Chalmers extras — extensive laboratory facilities, unparalleled application experience, factory supervised installation — guarantee complete dependability . . . continuous service.

A-5295

ALLIS-CHALMERS

some people have queer notions about

RADIOGRAPHY WITH ISOTOPES



Here's a typical multiple-specimen setup . . . seven castings radiographed simultaneously with a T.O. model 402 panoramic Cobalt 60 unit.

Many a plant, uneasily aware that it is missing the profits of radiographic inspection, still holds back for one mistaken "reason" or another. Here are some we run into . . .

"out of my league" . . . *costs too much*

Not so. An iridium 192 machine costing as little as $1700 may be fully adequate to your needs. *Indeed, average equipment cost is less than $2500.*

needs a *specialist* to run

On the contrary, a practical on-the-job training course in our Cleveland laboratory (free tuition to buyers) equips any intelligent employee with all he has to know.

takes forever to make a radiograph

Not so. You can x-ray 1" steel in 30 seconds, 3" sections in 4 minutes with the Cobalt 60 sources available today.

gamma radiographs are no good

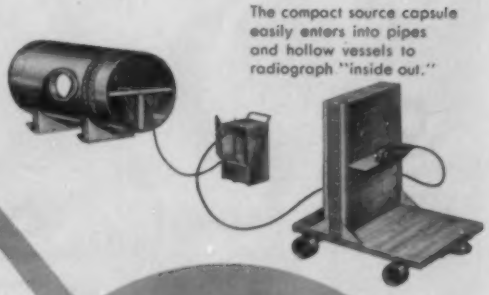
Not so. If you use the right source for the right job you'll have no trouble getting the 2% detail sensitivity required by exacting inspection codes.

it's dangerous; we're afraid of it

No reason to be: Technical Operations modern equipment is safe and simple-to-handle.

not for me; my stuff is different

We don't know what *your* business is . . . but if *whatever* you make (or buy or sell) needs "seeing into" for quality control, radiography (either gamma or x-ray) can profit you as it does others — *your competitors included.*



The compact source capsule easily enters into pipes and hollow vessels to radiograph "inside out."

costs nothing to find out

what radiography can do for you. Simply call in your local Picker representative* or write us outlining your problem (and if possible, sending typical samples). We'll make tests and tell you frankly whether radiography holds any promise for you. Because Picker offers both x-ray and isotope equipment, we have no axe to grind for any particular method.

**There's probably a Picker district office near you (see local 'phone book)*

PICKER X-RAY CORPORATION
25 South Broadway, White Plains, N. Y.

SOME OF THE TECHNICAL OPERATIONS GAMMA RADIOGRAPHY UNITS MARKETED AND SERVICED BY PICKER X-RAY

TO412A
Iridium 192 Unit

TO402
Cobalt 60 Unit

TO404
Cobalt 60 Unit

TO446
Cobalt 60 Unit

TO405
Iridium 192 Unit

TO416
Source Changer

one stop for everything in Picker x-ray **radiography and fluoroscopy**

Interior of a high temperature, hearth type Gas furnace specially designed for heat treating high strength steel casing

J&L speeds production, decreases costs . . . thanks to *GAS*

This Gas furnace at Jones & Laughlin Steel Corporation, Aliquippa Works, Pennsylvania, assures high strength characteristics formerly attained by adjusting the chemical composition of the steel. With Gas, J&L speeds production of special high strength seamless tubular products. Heat treating these products with Gas also saves tons of strategic materials like manganese, molybdenum and chromium, formerly used in the production of high strength seamless pipe.

For information on how Gas can help you with your production problems, call your Gas Company's industrial specialist. He'll be glad to discuss with you the economies and outstanding results you get with Gas and modern Gas industrial equipment. *American Gas Association.*

...and one for the pot!

Witches of old brewed heroic broths to encourage visions, prognostications, spells, and spasms. Even unrequited love yielded to these near-lethal potions. Add the tail of a cat, the ear of a rabbit, sixteen varieties of tree roots, and a few "trigger" ingredients, known only to the witches guild . . . and stand back!

Folklore ignores the witches' maintenance problems, but such overwhelming corrosives must have liquidated many a cauldron inventory. After all, the witches had no titanium.

Titanium is available today, and it is the most promising metal for the chemical, textile and pulp industries . . . or any place where severe corrosion presents forbidding maintenance or design problems.

Titanium is inherently passive to such vicious corroding agents as ferric, cupric, stannic and mercuric chlorides, and the hypochlorites. There is even little or no pitting or localized attack — a source of difficulty with practically all other metals. Stagnant conditions, surface deposits, fouling marine organisms and moist salt crystals are not troublesome to titanium. Strongly oxidizing agents in high concentrations and at high temperatures are readily handled with titanium. Slight additions of oxidizing agents to sulfuric, hydrochloric or phosphoric acid inhibit attack.

Titanium tubing, sheet, strip, plate, extrusions, bar and billet are all available from T.M.C.A.— and prices are dropping to competitive levels. T.M.C.A. technical service is available upon request.

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TITANIUM METALS CORPORATION OF AMERICA, 233 Broadway, New York 7, N.Y.

Speed for
aluminum extrusion . . .

Westinghouse

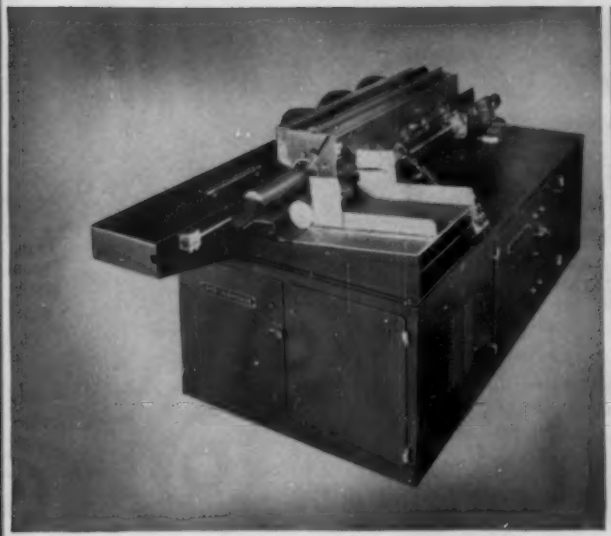
1. Greater efficiency in aluminum billet extrusion results from the speed and adaptability of Westinghouse induction heating.

C. P. Bernhardt
Engineering Manager,
Induction Heating Dept.

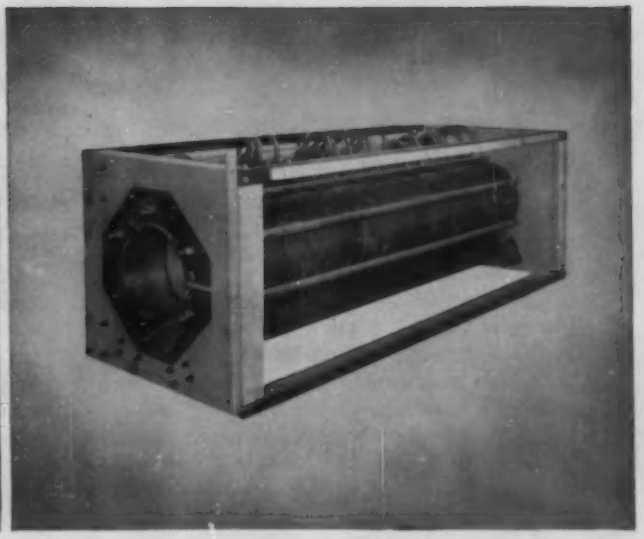
EXAMPLE: "Five thousand pounds an hour of 6-inch aluminum billets", reports Carl Bernhardt, "are heated to 1,000°F for heavy extrusion press operation." In supplying induction heating for this customer, Westinghouse saved 37% of the floor space needed for conventional furnace operation. Most important, high operating efficiency results from these five advantages in speed and flexibility:

- Short, 3-minute, start-up time. Stand-by heat losses are low.

induction heats billets on the run



2. Heating 6- or 8-inch billets to 1,000°F, this Westinghouse induction unit delivers up to 5,000 lbs of billets an hour.



3. Westinghouse coil design and engineering assures uniform heating from billet core to surface.

- Up to 80% cut in maintenance time and costs.
- Longer die life due to uniform billet heating... accurate, repetitive temperature control.
- Cooler, more productive working conditions.
- Pushbutton, automatic cycling of billet heating and handling directly to the extrusion press pickup.

For problem solving, call on Westinghouse technical leadership in induction heating research, design and engineering. You can be sure of complete service, too, through installation field engineering and follow-up. See your local Westinghouse industrial heating sales engineer or write, Westinghouse Electric Corporation, Induction Heating Dept., 2519 Wilkens Ave., Baltimore 3, Md. J-10450

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Machining Costs Cut 25%
by switch to NEW RYCUT 50

Logan Engineering Co. report shows how you can save up to 30% with a Ryerson leaded alloy

THE PROBLEM—This Chicago manufacturer of precision lathes faced a tough production problem from a time and cost standpoint. Lathe spindles have to be tough and hard with high wear resistance—so the steel Logan originally used was SAE 52100.

But the spindles were turned down and center-drilled from the solid to hole sizes as large as 1⅜". And ID's had to be accurate and free from scoring along the entire length of the spindles. 52100 provided the required mechanical properties but was slow cutting and created production difficulties and a high scrap rate.

Needed: A *free-machining* steel that would develop the high hardness levels, the toughness and wear strength required for the application.

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New Rycut 50 was a success from the start! Now, after two years, Harry Peterson, Logan plant superintendent, reports: "New Rycut 50 has saved us a consistent 25% of our former costs in the production of lathe spindles. Rycut's uniform machining and hardening properties have reduced scrapped parts to a minimum and the steel has proved satisfactory in every way."

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10th Western Metal Congress

Consolidated Program

Los Angeles, March 25 through 29, 1957

AMERICAN SOCIETY FOR METALS
AMERICAN WELDING SOCIETY (A.W.S.)
SOCIETY FOR NONDESTRUCTIVE TESTING (S.N.T.)
INDUSTRIAL HEATING EQUIPMENT ASSOCIATION (I.H.E.A.)
AMERICAN INSTITUTE OF MINING, METALLURGICAL AND PETROLEUM ENGINEERS (A.I.M.E.)
TITANIUM CONFERENCE – A.S.M. (Ti C.)

All Meetings at
Ambassador Hotel, Los Angeles

Monday, March 25

9:00 a.m. Advanced Methods of Machining and Metal Removal
9:00 a.m. Ti C. Titanium Progress to Date
10:00 a.m. S.N.T. Educational Session I
10:00 a.m. Ti C. Today's Uses and Design Criteria
Noon A.W.S. Luncheon – The Role of Welding in Industrial Advancement
12:30 p.m. Ti C. Group Luncheon
1:30 p.m. S.N.T. Educational Session II
2:00 p.m. Special Forming Techniques
2:00 p.m. Ti C. Titanium Fasteners
2:30 p.m. A.W.S. Welding Codes – Stimulant or Stumbling Block
7:30 p.m. S.N.T. Educational Session III (Don Bosco Technical High School)

Tuesday, March 26

8:45 a.m. S.N.T. Nondestructive Testing for the Aircraft Industries
9:00 a.m. I.H.E.A. Brazing and Sintering
9:00 a.m. A.W.S. Aircraft and Rocketry
9:00 a.m. A.I.M.E. Ultra High Temperature Materials
9:00 a.m. Ti C. Forming of Titanium
12:30 p.m. Ti C. Group Luncheon
2:00 p.m. Short Time Elevated Temperature Testing of Metals
2:00 p.m. A.W.S. Aircraft and Rocketry
2:00 p.m. S.N.T. Nondestructive Testing with Isotopes
2:00 p.m. Ti C. Panel on Forming of Titanium

Wednesday, March 27

9:00 a.m. Metals and Metallurgy in Electronics
9:00 a.m. A.W.S. General Welding Session
9:00 a.m. S.N.T. Radiography and Fluorescent Penetrants
9:00 a.m. A.I.M.E. Alloys for Future Airframes
9:00 a.m. Ti C. Machining of Titanium
12:30 p.m. Ti C. Group Luncheon
2:00 p.m. Aircraft Alloys for Thermal Flight
2:00 p.m. Ti C. Machining of Titanium
2:00 p.m. A.W.S. General Welding Session
2:00 p.m. S.N.T. Honors Session
2:00 p.m. S.N.T. Nondestructive Testing in Industry
5:00 p.m. S.N.T. Special Delegates' Meeting

Thursday, March 28

9:00 a.m. Corrosion and Metal Protection in Petroleum and Chemical Industries
9:00 a.m. A.W.S. General Welding Session
9:00 a.m. S.N.T. Nondestructive Testing in the Nuclear Energy Field
9:00 a.m. A.I.M.E. Light Alloys for Airframes
9:00 a.m. Ti C. Welding and Brazing
12:30 p.m. Ti C. Group Luncheon
2:00 p.m. Titanium
2:00 p.m. A.W.S. General Welding Session
2:00 p.m. S.N.T. Quality control

Friday, March 29

9:00 a.m. Ti C. Present Limitations and Future Potentials of Titanium
9:30 a.m. A.W.S. General Welding Session
12:30 p.m. Ti C. Group Luncheon
2:00 p.m. Ti C. A Look Into the Future

American Society for Metals

Monday, March 25

9:00 a.m. — Advanced Methods of Machining and Metal Removal

Panel Chairman: Manuel C. Sanz
Chief, Materials Research
North American Aviation, Inc.

Ultrasonic Machining
Donald A. Benbow, Sheffield-Western Sales Corp.

High Speed Machining
Kenneth L. Wilson, North American Aviation, Inc.

Ceramic Cutting
Paul Havener, Carborundum Co.

Electric Spark Discharge Machining
Fred. I. Regnier, North American Aviation, Inc.

Chem-Milling
Hugh H. Muller, Northrup Aircraft Corp.

2:00 p.m. — Special Forming Techniques

Panel Chairman: Gilbert A. Moudry
Chief Metallurgist
Harvey Machine Co. Inc.

Impact Extrusions for Aircraft Structural Applications
Gilbert A. Moudry, Harvey Machine Co. Inc.

The Fabrication of Metals for Nuclear Reactor Cores
F. R. Lorenz, Westinghouse Electric Corp.

New Developments in Impact Extrusions
Raymond A. Quadt, Hunter Douglas Corp.

Tuesday, March 26

9:00 a.m. — Brazing and Sintering
(Joint Meeting With Industrial Heating Equipment Assoc.)

Chairman: Elton E. Staples
Hevi Duty Electric Co.

Furnace Brazing
H. W. Webber, General Electric Co.

Salt Bath Brazing
Leon Rosseau, Ajax Electric Co.

Induction Brazing and Soldering
W. E. Benninghoff, Ohio Crankshaft Co.

Sintering and Brazing of Ceramics, Metals and Metallizing
R. L. Harper, Harper Electric Furnace Corp.

2:00 p.m. — Short-Time Elevated-Temperature Testing of Metals

Panel Chairman: Alan V. Levy
Supervisor
Marquardt Aircraft Co.

The Problems Connected With Testing
Alan V. Levy, Marquardt Aircraft Co.

Strength of Metals Undergoing Rapid Heating
Warren Smith and *Allen Robinson*,
U. S. Naval Ordnance Test Station

The Fluid Analogy to Aerodynamic Heating
T. C. McGill, Convair Div. of General Dynamics Corp.

Short-Time Creep of Structural Sheet
John A. Van Echo, Battelle Memorial Institute

Effect of Variables on the Properties
J. R. Kattus, Southern Research Institute

Wednesday, March 27

9:00 a.m. — Metals and Metallurgy in Electronics

Panel Chairman: Blair L. Molander
Group Leader, Metallurgy
North American Aviation, Inc.

Fabrication of Semiconductors
William V. Wright, Pacific Semiconductors

Processing and Purification of Silicon
D. K. Hartman, General Electric Co.

Germanium for Semiconductors
John Milek, North American Aviation, Inc.

Zone Melting and Zone Purification
Walter Pollitt, Hughes Aircraft Corp.

2:00 p.m. — Aircraft Alloys for Thermal Flight

Panel Chairman: A. H. Petersen
Group Engineer, Design
Lockheed Aircraft Corp.

Requirements Peculiar to Aircraft Design
Leo Schapiro, Douglas Aircraft Corp.

Material and Processing Requirements
F. R. Kostoch, North American Aviation, Inc.

Heat Treatable Corrosion Resistant Steels
R. B. Gunia, United States Steel Corp.

Tool and Die Steels for Thermal Flight
G. A. Roberts, Vanadium Alloys Steel Co.

Super Alloys for Airframe Structure
F. S. Badger, Haynes-Stellite Co.

Titanium Alloys for Thermal Flight
R. I. Jaffee, Battelle Memorial Institute

Thursday, March 28

9:00 a.m. — Corrosion and Metal Protection in the Petroleum and Chemical Industries

Panel Chairman: Martin Michaud
Materials Supervisor
Union Oil Co. of California

Economics of Material Selection
Martin Michaud, Union Oil Co. of California

Inspection and Corrosion Control
E. H. Tandy, Standard Oil Co. of California

Metallic Coatings for Steel
C. H. Sample, International Nickel Co.

Nonmetallic Coatings
Lester Morris, Coating and Fiberglass Research Co.

Cathodic Protection
L. L. Whiteneck, Pipeline Coating

2:00 p.m. — Titanium

Panel Chairman: Gordon A. Fairbairn
Supervisor
North American Aviation, Inc.

Forgings — *J. J. Russ*, Steel Improvement and Forge Co.
Extrusions — *Eric Berg*, Harvey Machine Co.
Castings — *Frank Caputo*, Oregon Metallurgical Corp.
Heat Treatment — *L. S. Busch*, Mallory-Sharon Titanium Corp.
Welding — *Russ Meredith*, North American Aviation, Inc.
New Alloys — *H. D. Kessler*, Titanium Metals Corp.

American Institute of Mining, Metallurgical and Petroleum Engineers

Tuesday, March 26

9:00 a.m. — Ultra High-Temperature Materials

Panel Chairman: Pol Duwez
California Institute of Technology

Materials for Aircraft and Missile Applications
Alan V. Levy, Marquardt Aircraft Co.

Role of Molybdenum for Missiles
Robert R. Freeman, Climax Molybdenum Co.

Cermets for High-Temperature Service
John C. Redmond, Kennametal Inc.

Graphite as a High-Temperature Material
J. E. Howe, North American Aviation, Inc.

Wednesday, March 27

9:00 a.m. — Alloys for Future Airframes

Panel Chairman: Campbell W. Funk
Aerojet-General Corp.

Fabrication of High-Temperature Airframes
Fred Baisch, Boeing Airplane Co.

Welding of Precipitation Hardening Stainless Steels
George E. Linnert, Armco Steel Corp.

Conservation of Nickel in High-Temperature Alloys
E. E. Reynolds, Allegheny Ludlum Steel Corp.

Thursday, March 28

9:00 a.m. — Light Alloys for Airframes

Panel Chairman: Harold H. Block
AiResearch Corp.

Aluminum Alloys for Elevated-Temperature Service
Wayne A. Reinsch, North American Aviation, Inc.

Depressive Deformation for Stress Relief
R. E. Klient and *F. G. Janney*, North American Aviation, Inc.

Magnesium Alloys for Airframes
F. Keith Lampson, Marquardt Aircraft Co.

American Welding Society

Monday, March 25

Noon — Kick-off Luncheon

Chairman: Charles W. Concannon
Sales Manager
Basco, Inc., Los Angeles

The Role of Welding in Industrial Advancement
J. J. Chile, President, A.W.S.
Director of Research, A. O. Smith Corp.

2:30 p.m. — General Session

Welding Codes—Stimulant or Stumbling Block
T. B. Jefferson, Editor, *Welding Engineer*

Tuesday, March 26

9:00 a.m. — Aircraft and Rocketry

Chairman: Mario Ochieano,
Lockheed Aircraft Corp.

Recent Developments on Magnetic Force Welding
Jack Funk, Precision Welder and Flexopress Corp.

Aluminum Alloys for Rockets
Walter S. Tenner and *Paul T. Barnes*,
U. S. Naval Test Station

Resistance Welding Titanium Alloy Structures
William R. Gain and *Howard E. Woodward*,
Boeing Airplane Co.

2:00 p.m. — Aircraft and Rocketry

Chairman: Leo West
Douglas Aircraft Co.

Counter Tubes for Resistance Welding Controls
J. J. Riley, Taylor-Winfield Corp.

Stress-Corrosion of Titanium Weldments
William S. Arter, North American Aviation, Inc.

Vacuum Brazing of Sandwich Structures
G. Jewett Crites, Engineering Consultant, El Segundo

Wednesday, March 27

9:00 a.m. — General Session

Chairman: Russell Graves
The Fluor Corp.

Welding for Nuclear Pumping Applications
Frank R. Drahos, Byron Jackson Co.

Ultra High-Strength Weld Metal for Airframes
D. C. Smith, Harnischfeger Corp.

Filler Materials for High-Strength Low-Alloy Steels
Frank G. Harkins, Solar Aircraft Co.

Weld Roll Planishing, the Weld Helper
Harlan Meredith, Airline Welding and Engineering Co.

2:00 p.m. — General Session

Chairman: H. B. Evans
Associated Piping and Engineering Co.

Field Welding of Pressure Piping
A. M. Croswell, Bechtel Corp.

Inert Gas Shielded Arc Welding of Aluminum
Paul Dickerson, Aluminum Co. of America

Weldability of High-Temperature Alloys
R. P. Culbertson, Haynes Stellite Co.

Thursday, March 28

9:00 a.m. — General Session

Chairman: Leo Gatzek
Bendix Aviation Corp.

Welding of Light Gage Materials
T. McElrath, Linde Air Products Co.

Evaluation of Hard Facing Materials
Dave Rankin, Rankin Manufacturing Co.

A New CO_2 Welding Process
A. F. Chouinard and *R. T. Monroe*,
National Cylinder Gas Co.

Tool and Die Welding
Patrick S. Doyen, Welding Equipment and Supply Co.

(*Continued on next page*)

A.W.S. — Thursday (Continued)

2:00 p.m. — General Session

Chairman: A. B. Bennett
Solar Aircraft Co.

High-Temperature Silver Brazing
A. M. Setapen, Handy and Harmon Co.

Selection of Inert Gas Shielded Processes
C. B. Robinson, Air Reduction Pacific Co.

The Inert Gas Welding of High-Nickel Alloys
K. M. Spicer, International Nickel Co.

Friday, March 29

9:30 a.m. — General Session

Chairman: Art Williams
Consolidated Western Steel Co.

Iron Powder in Arc Welding Electrodes
Richard K. Lee, Alloy Rods Co.

Causes of Weld Metal Cracking
Glen Faulkner, Battelle Memorial Institute

Constant Voltage Type Welders
L. P. Henderson, M & T Welding Products Corp.

Society for Nondestructive Testing

Monday, March 25

10 a.m., 1:30 and 7:30 p.m.—Educational Sessions

Tuesday, March 26

8:45 a.m. — Nondestructive Testing for the Aircraft Industries

Chairman: R. E. Kleint
North American Aviation, Inc.

Statistical Methods for Ultrasonic Inspection
Murvel J. Bratt, General Electric Co.

High-Strength 7075 Aluminum Alloys
G. B. Mathers and R. E. Kleint, North American Aviation, Inc.

Ultrasonic Flaw Plotting
Benson Carlin, Alcar Instruments, Inc.

Flaw Detection, Alloy Identification and Determination of Properties by Eddy Currents
Richard Hockschild, American Testing and Control Co.

Flaw Evaluation by Ultrasonics
William C. Hitt, Douglas Aircraft Co.

Magnetic Particle Inspection
Vernon I. E. Weigand and Edward H. Honerkamp, General Electric Co.

2:00 p.m. — Use of Isotopes

Chairman: Dana E. Elliot
Los Alamos Scientific Laboratory

The AEC's Relation to the Industrial Atom
Robert F. Barker, U. S. Atomic Energy Commission

Cesium-137 for Radiography
Merle L. Rhoten and Samuel A. Wenk, Battelle Memorial Institute

Thulium-170 for Industrial Radiography
Dana E. Elliot and James W. Dutli, Los Alamos Scientific Laboratory

Quality Control of Sealed Objects
Clifton W. Reed, Reed-Curtis Nuclear Industries, Inc.

Gamma Radiography of Light Metals
Eric T. Clark, Technical Operations, Inc.

Wednesday, March 27

9:00 a.m. — Radiography and Fluorescent Penetrants

Chairman: Wallace J. Erichsen
Westinghouse Electric Corp.

Large-Source Cobalt in Radiography
Clarence A. Karrer, Crucible Steel Casting Co.

Speedy Multiple Film Techniques
Ralph E. Turner, Eastman Kodak Co.

Refinements in Radiographic Techniques
Harold S. Wyckoff, Triplett and Barton, Inc.

Role of Brightness in Fluorescent Penetrants
Donald W. Parker and J. Thomas Schimdt, Magnaflux Corp.

Flexible Fluorescent Screens
K. G. Roberts, Naval Research, Dockyard Laboratory, Halifax

2:00 p.m. — Honors Session

Chairman: Richard F. Holste
National President
Society for Nondestructive Testing

The Du Pont Award
Recipient: Eric A. Kolm, Raytheon Mfg. Co.

The Lester Lecture Award (posthumously)
Recipient: Edgar O. Dixon, Presentation to William Dixon, a son

3:00 p.m. — Nondestructive Testing in Industry

Chairman: John Battema,
Ferro-Spec Laboratory, Inc.

Corrosion Inspection With Ultrasound
Donald C. Erdman, Sperry Products, Inc.

Porosity-Graded 195 Alloy
Irving J. Feinberg, Naval Ordnance Laboratory

Calibration of Reflectoscope
H. E. Van Valkenburg, Sperry Products, Inc.

Special Film Presentation
Directed by George H. Prudden, Lockheed Aircraft Corp.

Thursday, March 28

9:00 a.m. — Nuclear Energy Applications

Chairman: W. J. McGonnagle
Argonne National Laboratory

The Immersed Ultrasonic Inspection of Tubing
R. B. Oliver and J. K. White, Oak Ridge National Laboratory

Radiography of Materials for Nuclear Energy
J. W. Dutli and D. E. Grimm, Los Alamos Scientific Laboratory

Lamb Waves in Ultrasonic Testing
D. C. Worlton, General Electric Co.

Nondestructive Testing of Materials for Reactors
O. R. Carpenter, Babcock and Wilcox Co.

Measurement of the Uranium in Fuel Elements
W. J. McGonnagle and G. E. Bradley, Argonne National Laboratory

2:00 p.m. — Quality Control

Chairman: W. Stump
Dow Chemical Co.

Accelerated Life Tests
Harry G. Romig, Summers Gyroscope Co.

Gamma Radiation for Density Measurement
Philip E. Ohmart, The Ohmart Corp.

A Reference Wedge X-Ray Gage
Stanley Bernstein, General Electric Co.

Proper Frequency for Eddy Current Testing
Bernard H. Robinson, Magnaflux Corp.

Automatic Recording, Sorting and Controlling
Peter K. Bloch, Branson Instruments, Inc.

Metal Progress
Volume 71, No. 3 March 1957

The Need for Less Sulphur in Deoxidized Steel

*By H. W. McQUAID and NORMAN P. GOSS**

Since more than 0.020% sulphur in aluminum-killed, fine-grained steel produces undesirable ferrite in supposedly all-martensitic microstructures, the authors recommend that American quality steel manufacturers install special equipment for rapid desulphurization, as is already being done in several European steelworks.
(D11n, ST, *S*, *Al*, AD-p35, 9-19)

SULPHUR today is one element in steel which is accepted by practically every steel user as a necessary evil and, except when specified deliberately as an aid to machinability, is looked upon as undesirable. It is detrimental to surface soundness as well as to internal cleanliness and transverse physical qualities. Steelmakers believe that sulphur raises the surface conditioning costs and lowers the yields. Most users of heat treating grades, manufacturing parts which are subjected to severe stressing in service (such as aircraft, bearing and special gear grades), set the limits as low as commercially practicable and hope for the best.

In many applications the important adverse effects of sulphur, when in combination with strong deoxidation additions such as aluminum, are not very widely understood, or much stronger efforts would be made to do something about it. One reason is that the effects show up to the greatest degree in a transverse direction, and not nearly as strongly in the longitudinal tensile test piece. However, the situation is quite different in low-temperature transverse impact testing. In service, a particularly bad situation arises from the ferrite films which form at the primary grain boundaries of the quenched microstructure, and in which are the starting points for stress concentration and fatigue failures.

Today the American steelmaker is making little if any progress in sulphur control. Much of it originates in the coal used to make coke and produce gas, and in the fuel oil used for melting on the openhearth. The result is undesirably higher sulphur in hot metal and cold pig iron from the blast furnace, and also a pickup in openhearth melting. Due to the low quality of pur-

*Consultants, Cleveland, Ohio.

chased scrap, there is at present a tendency for the charge to melt in with a definitely higher sulphur content than formerly – especially in the electric furnace – a tendency which is quite widespread and will increase as the demand for scrap increases. The first result is increasing delays and costs in the melt shop, due to extra time for sulphur reduction with its severe wear and tear on the furnaces due to the higher temperature and the necessary higher lime slag. This state of affairs, combined with the practically universal use of aluminum to produce the "fine grain" steels, markedly increases the conditioning costs, especially in the low-carbon, plain carbon grades, for reasons that will be discussed later in this article.

We begin our review by stating that in the special aircraft, bearing, gear and other highly stressed steels where the *best* possible quality is desired, every effort is made to get a steel which is as low in sulphur as commercially possible. Much has been written about the two principal forms in which sulphur exists in steel, and we have been told that all that was needed to overcome the adverse effect of sulphide existing as an intergranular film (Type II) was to work throughout a heat with a relatively high minimum of manganese in the bath; the iron sulphide would then change to the spheroidal or block type of inclusion (Type I), more or less harmless. Intergranular films are greatly elongated in the direction of working and give the rolled bar strong directional properties. Thus, the sulphide film would interfere but little with carbon diffusion in a longitudinal direction but would block it in a transverse direction, resulting in a relatively continuous and uniform martensite longitudinally after quenching – but because of the carbon-free high-sulphide boundaries, heavy ferrite films would also form parallel to the axis even after the best of quenching. A fully hardened piece would contain boundaries of ferrite throughout the martensite, resulting in a sensitivity to fatigue failure and relatively poor transverse properties – especially those measured by subzero impact tests – which would make the steel unsuitable for such parts as bearings, torsion springs, artillery gun barrels, gears and many highly stressed important parts.

Steel Refining Practices

For at least 50 years it has been assumed that manganese is good medicine for sulphur. We wish to emphasize that almost any such beneficial effect it might have had disappears in the presence of much more than 0.005% of aluminum in the steel! There is some mystery about the sulphur and aluminum combination, yet much hard experience with the hot shortness (surface condition) of high-sulphur steel (with and without aluminum) would indicate that the *degree* of oxidation is the critical factor and the beneficial effect of the manganese may in some way be connected with this.

We have known for a long time that, when making a low-carbon high-manganese steel *without any addition* of aluminum or silicon, any hot short tendency as indicated by surface defects in the blooms or billets could be much reduced if we ran up the iron oxide in the slag high enough. Since higher iron oxide can be carried in the tapping slag in a 0.10% max. carbon steel (if necessary above 30% in the electric furnace), we could eliminate practically any hot short tendency even with the highest of sulphur additions (0.250 to 0.300%). Thus it was established that, for the lowest conditioning costs in the high-sulphur steel, the iron oxide in the tapping slag must be above a high minimum figure (30%); any figure below this showed up quickly in hot shortness*, bad surfaces and high conditioning costs. This was true even though the manganese were above 1.20% in the steel, in which case the high iron oxide slag could only be obtained because the carbon was brought below 0.10%.

Now comes the use of aluminum for grain size control. Aluminum is a strong deoxidizer; it eliminates practically completely any iron oxide in solution in the liquid steel, forming aluminum oxide – which, by the way, has a markedly adverse effect on cutting tool life. Manganese, on the other hand, is a relatively poor deoxidizer; in spite of the rather high manganese content in the low-carbon high-sulphur steel, much iron oxide can remain when the tapping slag has above 30% FeO. Less than 0.010% of aluminum in the steel will reduce the iron oxide in solution very close to zero.

*Practically every ingot, being a casting, has some internal, intercrystalline cracks or separations and these when subjected to definite compression stresses by forging or rolling at temperatures above 2000° F. will usually weld up and disappear – that is, they will *unless* the intercrystalline separation is caused by the precipitation of films, iron sulphide or bubbles of hydrogen or nitrogen, when it will be very difficult if not impossible to weld. The discontinuity will not decrease when hot worked but probably increase. This is what is known as a "hot short" condition and its prime cause in fine-grained steels is the addition of aluminum to heats which have more than 0.020% sulphur.

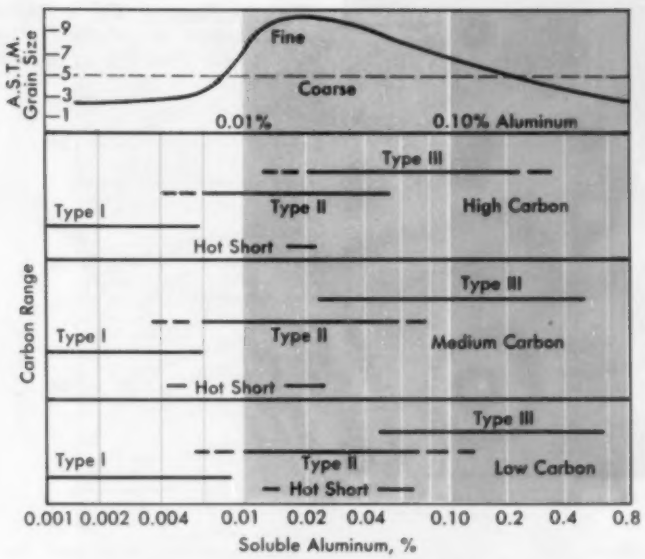

Fig. 1 – Type of Sulphide as Related to the Aluminum Addition, Carbon Content and Grain Size. Adapted from "Effects of Various Deoxidizers on the Structures of Sulphide Inclusions", by C. E. Sims, H. A. Saller and F. W. Boulger, Transactions, *American Foundrymen's Society, 1949*

It is interesting to note that it is *after* the iron oxide in the molten steel has been reduced to almost zero by the aluminum addition that any aluminum added starts to reduce the grain size. In fact, it is the *first* addition of aluminum added *after* the elimination of iron oxide that is the biggest factor in grain size control. (Some authorities say this is because the aluminum combines with nitrogen to form the nitride.) It is also important to note that, in spite of any manganese present, the Type II sulphide is formed after any iron oxide is reduced by the aluminum, and Type II sulphide is formed more or less coincidentally with the aluminum addition required for minimum grain size. After this optimum addition, any more aluminum results in a gradual grain coarsening effect and a gradual change of the sulphide from the film Type II (responsible for hot shortness) to the nodular Type III. This change is shown diagrammatically in Fig. 1.

It seems quite logical to relate the causes which result in the finest grain with the causes which result in Type II or film-type sulphides and the maximum tendency to be hot short in rolling or forging. Since this grain size and adverse sulphide effect has been frequently related directly to the iron oxide (or rather the *lack* of iron oxide), it would be interesting to know why a slag with high *minimum* iron oxide promotes coarse grain and overcomes hot shortness. When we analyze this problem, we will find that this occurs only in very low-carbon, low-silicon and aluminum-free steels; in spite of the high sulphur, the surface conditioning costs will be close to zero. If the slag iron oxide drops below 30%, surface troubles start, and as soon as it gets close to 20% the conditioning costs really go up.

It is quite obvious that only a very few grades of steel can be tapped with the iron oxide in the slag above 30% and the carbon below 0.10%. However, the fact remains that the addition of aluminum to molten steel for grain size control to meet the steel buyer's specification is accompanied by an undesirable sensitivity to even relatively low sulphur, not only because of hot shortness effects but also because of ferrite separation in quenched martensite structure, and because of strong directional properties which are induced.

Thus we can state that as long as fine grain size is almost universally specified, the effect of sulphur even when below 0.030% will be bad (costly) both to the steel user and the steelmaker. This is especially true of plain carbon, low-carbon steel where the usual steel buyer unthinkingly specifies a "fine grain steel". He gets an aluminum-treated steel, costly to the steelmaker because of its high conditioning costs and low yield, and costly to the purchaser because of its poor results in heat treating, poor tool life, and poorer machinability and reduced transverse properties.

Effect of Ingot Practice

What is really important in the "quality" of steels used for important highly stressed mechanical parts of today's machines? We believe that what the buyer hopes to get for his expensive, highly stressed, special heat treated aircraft, bearing, or other part is steel which has a structure which, on being heated above the critical range, will dissolve all the iron carbide it contains, and the carbon (or carbide) will diffuse uniformly throughout the austenite. On quenching, he expects this steel to transform into a 100%

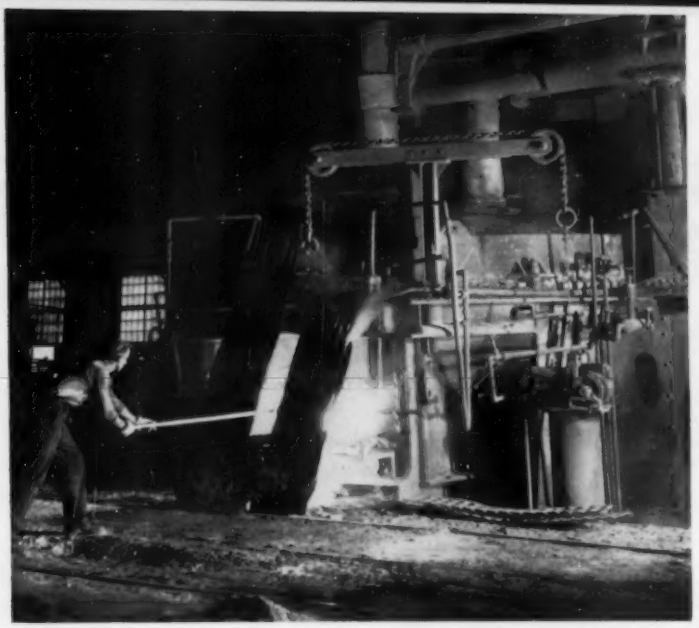

Fig. 2 – Slagging Off a 35-Ton Arc Furnace at Midland Plant of Crucible Steel Co. of America

martensitic structure, completely uniform, in those regions where the critical quenching rate is exceeded. He also expects that this uniform martensite, free from ferrite, bainite or fine pearlite, can be tempered to give the desired combination of strength and ductility in the finished part, with no highly local areas of low strength caused by ferrite or nonmetallic inclusions.

This of course is not easy to accomplish. When we stop to think about all the factors which interfere with the production of 100% martensite, no matter how fast a quench is available, we must be ready to make some important concessions. One of the most important of the practical facts of life in the steel plant, which result in segregation and concentration of undesired nonmetallics and ferrite in the quenched piece, is the ingot itself. A large ingot prevents any assurance that the quenched and drawn part will be free from actual microcracks and films of low strength. This arises from the highly uncertain and extremely nonuniform microstructure of that large steel casting that is known as the ingot.

American commercial steelmaking now involves the pouring of a large steel casting weighing several tons, poured into a heavy iron mold. As it solidifies it develops large chill crystals which first grow rapidly at right angles to the surface and then in a more equi-axed manner as solidification progresses inward. Certain elements such as sulphur, nitrogen and hydrogen are quite soluble in the liquid but quite insoluble in the solid steel, and these come out of solution as the chill crystals form. Under certain conditions, they concentrate around the solidified crystals as boundary nonmetallic films which interfere with the diffusion of carbon between solidified metal and the remaining mother melt, so providing the first interference with the formation of uniform metallic structure in the finished steel part.

Subsequent mechanical working of an ingot tends to break up these segregates into a more disperse form, and this is why we can feel more confidence in a forging or small rolled part which has been greatly reduced from the as-cast structure of the ingot. It is for the same reason that such parts as large turbine rotors or similar forgings made from aluminum deoxidized ingots (which have relatively little reduction from ingot to forging) are so extremely sensitive to ingot boundary segregation of nonmetallics such as sulphur and hydrogen.

Since nearly all high-grade steel is now cast in a large mass and weakening segregates are to be expected, we must make every effort to eliminate the causes as well as the effects of such segregation. Here again the first approach would be to eliminate sulphur and hydrogen, especially in aluminum-killed grades, from the molten steel. Another move in the right direction would be to reduce the size of the cast ingot to the very minimum, by continuous casting of billet size.

In a large ingot there is every opportunity for the segregation of those elements which are less soluble in the solidified steel than in the melt. The segregates are usually of microscopic size in the finished bar. This segregation also reaches a maximum of concentration in the last

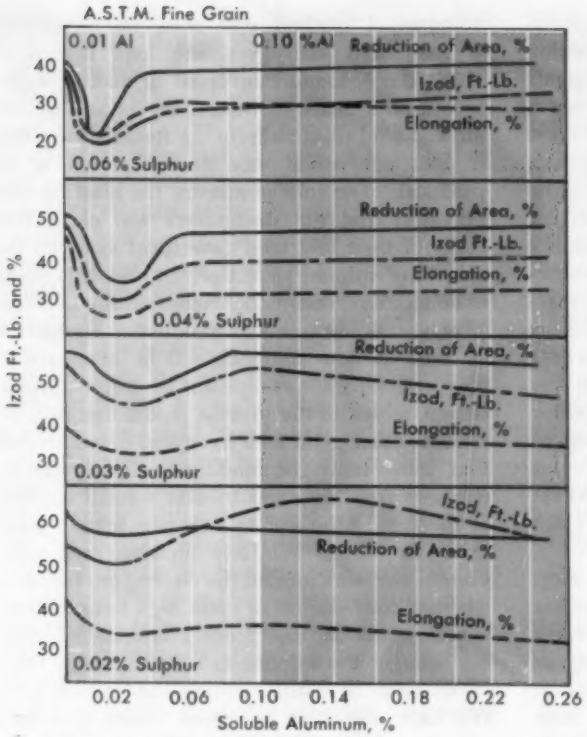

Fig. 3 – Quantitative Effect of Aluminum on Ductility and Impact Strength of Grade B Cast Steels. From "Effect of Aluminum on the Properties of Medium Carbon Steel", by C. E. Sims and F. B. Dahle, Transactions *of the American Foundrymen's Assoc., 1938*

metal to freeze at the grain boundaries of large chill crystals and in the metal originally located at the top central portion of the ingot. To some degree, it exists in microscopic form throughout the whole ingot, especially in places where critical combinations of a strong deoxidizer such as aluminum are present with sulphur, hydrogen and nitrogen. This is a natural effect. Except for a very short time during the initial chilling against the mold wall, selective freezing is going on throughout the whole period of solidification. Everything in Fig. 3 that Sims and Dahle showed was true about the effect of aluminum and sulphide inclusions on the ductility of a steel casting is equally true about a steel ingot. Definite steps should be taken either to eliminate sulphur from the ingot composition, avoid the use of a critical amount of a strong deoxidizing addition such as aluminum, or cast continuously in small cross sections – or all three of these precautions together.

Welding, as it is usually performed, produces a cast structure which is sensitive to boundary precipitates of sulphur and hydrogen, especially in the aluminum-killed fine-grained type of steel. To avoid the harmful effects of such intergranular sulphides, sulphur in the fine-grained chromium-nickel-molybdenum steel for welded aircraft propeller blades was specified as 0.010% max.

While 0.010% max. was selected because of the importance of this aeronautical part, other instances could be given where steels with sulphur limited to this amount resulted in very important improvements, especially in transverse properties in gun forgings. In one case, forgings were made having a sulphur content close to or even under 0.010% and the improvement in transverse subzero impact test results and ductility was quite marked over heats with sulphur in a range above 0.020%. (This was a chromium-nickel-molybdenum steel with no aluminum added at any time, but to which 0.15% vanadium had been added in the furnace at tap.)

Low sulphurs are also of value to the buyer of special requirement, flat rolled, low-carbon products. Sulphur well below 0.020% will make an important improvement in high-silicon electrical strip steels, especially when processed into special grades involving grain orientation. In fact, the extra-low sulphur is an important factor in developing extra high and uniform physical and electrical properties in both the longitudinal and crosswise directions. This effect is traceable to the sulphide segregation in the ingot already noted, and to the effect of deoxidation on the sulphide type and distribution. A similar effect – but to a less degree – is noted in continuous annealed auto body and extra deep drawing steel.

0.020% Max. Sulphur Recommended

In some rolled bars it has been observed that when the sulphur decreases below 0.020%, the silicate inclusions also decrease to an important degree. This indicates a direct connection between silicate inclusions, deoxidation, and the type of sulphide segregation in the ingot – again, an important factor in special bearing and aircraft steels.

From the above discussion of sulphur and aluminum in steelmaking it becomes evident that the two form a bad combination, especially in

steel for heat treated, highly stressed special requirements, as well as for extra deep drawing sheet and strip stock, steel castings, and ingots for important large forgings. Usually when aluminum is added to such steels, it is to meet a fine grain specification, and special emphasis is put on low sulphur. Unfortunately, the aluminum which develops the finest grain is just the amount which has the maximum tendency to produce the film type of sulphides with attendant hot shortness, ferrite formation in the martensite, and poor transverse properties. Sims and Dahle in 1938 showed that this adverse effect of aluminum was practically eliminated in the steels they tested when the sulphur was below 0.020%. For this reason it would seem logical to recommend that in any steel for an important application the *maximum* sulphur should be set at 0.020% if aluminum is to be added for grain size control.

Little is now being done in the melting shop to overcome this extremely costly combination of sulphur and aluminum, except to work longer with heavier and more alkaline slags in the openhearth and higher temperatures and the time-honored, slow, uncertain calcium carbide lime slags in the electric furnace. For the most part, steelmakers seem to be satisfied with things as they are. However, when the advantages of much lower sulphur limits are discovered by the user as well as the maker of fine-grained (aluminum treated) steels, means will be found for their commercial production.

In our opinion it is time for the steel user (and producer) to wake up and insist that if aluminum is going to be added to a heat of the special requirement steel for so-called grain size control, the sulphur must be below 0.020%.

While it might be agreed that sulphur below 0.020% would be highly desirable in all special grades of fine-grained steel, our present methods of eliminating sulphur from the bath would make such limits very costly to meet. It will only take some realistic studies, however, to conclude that such steels will be worth what they cost in improved production and performance of the finished part, to say nothing of the lower conditioning costs in the steel mill. The steel companies will have to make the necessary improvements in equipment or install power devices which will remove sulphur from hot metal at the blast furnace or mixer, or from the molten charge from the electric furnace or openhearth. All that is needed is the necessary pressure from the steel purchaser. A satisfactory commercial method will then be developed.

One could easily get into long arguments about the economics involved in making extra-low-sulphur heats. One can expect an immediate and loud reaction from the steel industry that it does not make sense and it is not at all practical. The coke producers, the blast furnace operators and the steelmakers will claim that many of their best men have spent years on the subject of sulphur reduction, and what is being done today represents the commercially possible. This is no doubt true with production equipment as it is. A new approach will be necessary in new and separate equipment of single-purpose design, added to the present production line.

Some other good men have also demonstrated that under the right conditions sulphur can be removed from iron and steel in a small fraction of the usual time and to a degree seldom mentioned in public. We have ourselves seen occasions in our work around the electric arc furnaces where a combination of extra high temperature, violent agitation, and fresh limestone addition has brought the sulphur in a few minutes from 0.060 down to 0.010%, during the carbon boil. We have also seen occasions where a melter would spend an hour getting the sulphur down ten points in a deep dead bath, under a cold slag of heavy burnt lime and calcium carbide — all the while giving most of his attention to the reaction of calcium carbide and water.

Special Refining Equipment

The importance of fluidity in a highly alkaline slag, high temperature of steel in the bath, and a continuous — almost emulsified — contact between slag and every possible part of the metal is well known, if sulphur is to be *quickly* reduced to a harmless figure. It is difficult in the modern large melting furnace. The reduction of sulphur is badly handicapped in both the electric and openhearth by the relatively poor area of contact between the barely liquid slag and liquid metal, and the definite lack of turbulence or agitation of the bath metal in close contact with an exceptionally fluid slag.

If the above requirements are met, and the temperature is approximately 3000° F., sulphur can be cut rapidly to a very low figure. In some electric furnace practice, sulphur can be reduced to almost any desired amount during the carbon boil.

One of the basic works on desulphurization was published by Dürrer, Hellbrügge and Marincek in *Archiv für Eisenhüttenwesen* in

1941 under the title "Desulphurization With Acid Slags". They showed that under specified conditions, combinations of SiO_2, CaO and a flux (Al_2O_3) would quickly remove sulphur from a very high level down to a very low level if the temperature were high enough. The surprising fact emerged that silica alone (100% SiO_2 slag) was very effective under certain conditions and would reduce the sulphur content of a hot metal from 0.100 to below 0.010% in a few minutes at 3200° F. The function of the alkaline addition (lime) to the silica was to achieve the same result at lower temperatures. The best result was had with a slag whose composition corresponded to that for highest fluidity.

Other published work has indicated that sodium compounds are better sulphur eliminators than calcium compounds, but since the former react rapidly with superheated refractories they are not usually considered as being practical. This objection might be removed by constructing a separate chamber for eliminating sulphur, so designed as to protect the refractories from the sodium compounds. Such a simple method would involve equipment whereby the very hot and fluid reacting (desulphurizing) slag could be carried in intimate contact with the agitated and very hot surface of a relatively thin sheet of liquid steel, and the steel would separate the fluid caustic slag from the refractory.

The work done by Perrin in France and Kaling in Sweden has indicated that the prime factors for speedy sulphur elimination are large contact areas per ton, highly agitated and fluid intimate contact, and high temperature. This, of course, is the basis for the activity of most chemical reactions. Perrin's conclusion is sound, namely, that the rapid refining obtained in his process is due to vigorous high-temperature agitation approaching emulsification. Exactly the same conditions will apply to rapid desiliconizing and decarburizing.

The sooner such special equipment is developed the sooner American industry will enter a new era of better and more economical steel production. A thin sheet of liquid metal can be formed in several ways – on a horizontal rotating table, on a continuous belt, in a closed rotating retort (batch type), or in a rotating horizontal retort through which the charge passes continuously.

When we can produce the extra-low-sulphur steel needed so badly both by the quality steel user and the special steel producer, we can simultaneously (and possibly in the same equipment) reduce the silicon and the carbon to a low figure. The equipment would not be difficult to design; it would be used in series with a pig machine, the mixer, or the melting furnace, and it lends itself to high tonnage and relatively low investment. Work done to date shows that the reactions proceed with amazing rapidity. All processing can be completed in seconds if the area per ton of contacting and reacting metal and slag of extra fluidity is sufficiently high. This indicates a relatively small continuous reacting chamber of simple design, with a capacity of several tons of finished product per minute. Any drive for practically sulphur-free (0.020% max.) steel of high quality and fine grain size will result in several valuable byproducts, namely, a new and much brighter picture as to scrap, low conditioning costs and good production rates, especially in the openhearth department.

Foundry Iron – Such a development would also be of great value to the foundry industry. The blast furnace and cupola would gain some important economical advantages by being able to use coke with a much higher sulphur range and at the same time cutting down on the lime and the necessary coke per ton of iron because the sulphur (and the silicon) could be easily removed from the hot metal after it leaves the furnace.

Sulphur has some effects in the foundry which are not talked about very much but are important. For example, its influence on graphite formation during the solidification of iron. In gray iron castings a small percentage of sulphur (0.03% min.) will expedite the formation of flaky graphite (and prevent the nodular form). Hence, low-sulphur gray iron is used in the process developed by Ihrig to produce a ductile cast iron which approaches steel in properties. The process consists of adding magnesium chloride and calcium silicon to low-sulphur gray iron in the cupola runner or the ladle. Use of such improved metal will grow as its superior economics and physical properties become more widely known.

Such an important return would accrue to both the steel and iron producer and the steel and iron user that American experts on high-temperature chemistry and mechanical engineering should work together to solve the problem. In a relatively short time after such a program was started, in our opinion, the commercial equipment necessary will be available. Eventually 0.020% (max.) sulphur will become standard for quality steel in the industry.

Research Management

*By ARTHUR R. LYTLE**

An informal address (somewhat condensed) before the meeting of the Atomic Energy Commission's Welding Committee in Oak Ridge last September, wherein the speaker outlined the responsibilities and relationships between corporation executives, laboratory managers, and specialized personnel necessary to achieve commercial results from organized research. (A9g)

IT IS A TRUISM that research, during the last half century, has brought about tremendous changes in our entire method of living and has completely modified our social structure. Those of us who are close to research activities, however, are sometimes amazed at the confidence placed by people in other professions and in businesses of all sorts, upon the mere fact that research will be undertaken. While it is true that most problems can be solved if enough work and time are spent on them, in a good many instances there must be a little hesitation on the part of responsible individuals as to the *timeliness* of such research effort. Perhaps it is because of such unfeigned confidence in the capabilities of research that the tremendous accomplishments have been attained! Such an attitude is undoubtedly a strong morale builder when the chips are down on a tough problem.

It might be profitable for once to consider the factors that could deter successful research – therefore factors that must be given serious consideration. Much has been said about the ways whereby laboratories can be set up, organized and implemented, assuming that left on their own such laboratories always come up with favorable and desirable results. Of course this is not necessarily true; many are the actions or lack of actions by management and the research men themselves which definitely can deter, handicap and otherwise reduce the productivity of a research effort and even the possibility of its success.

If we define research as those activities which introduce into an enterprise or organization the possibility of producing new products or using new processes which differ appreciably from those in which they are normally engaged, research embraces a pretty broad spectrum of activities. In describing the factors that might hamper a research program, at least three different levels of responsibility must be considered, namely, top executives, local or laboratory management, and the individual scientist.

Top Management Initiates

Top management determines in the first place that research is necessary and in a broad sense indicates the general area of the activities. The other obvious responsibility of top management is to see that the necessary money is provided.

In addition to these primary functions, the first major responsibility that management must assume when setting up a research facility is to provide for the new plant, new operating staff and new sales organization that automatically follow any decision to enter a new business or to introduce a new product which results from the organized research. Most of the new products and new processes will embrace entirely new technologies – usually for the full breadth

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and depth of the operations. Experts in many fields, perhaps seemingly unrelated to the one in question, are needed to understand and study all the ramifications of a new project.

If, for instance, the product is a new metal, experts in mineralogy, ore processing, smelting, new chemical engineering methods, solid state and surface physics, analytical chemistry and chemistry of new materials are needed in the fundamental studies. Men must also be provided who can not only appraise the product as it might be used commercially but also find out in a preliminary way the needs of industry or the possible uses to which industry might put new products of a similar nature. Simultaneously, cost studies of the process must be made, at least in a preliminary manner, by the members of the research staff in order to guide the project properly. An active New Product Promotion Group must be set up to supply the laboratory with information concerning the desirability, acceptability or deficiencies of such new products or processes as are brought to their attention. If this department is undermanned in proportion to the research effort, a very serious deterrent will exist to making the research program successful.

Provision must also be made by top management to take the result of research as soon as it has been demonstrated to have a favorable market, and set up a facility in what might be called a New Product Department for production on a moderate scale. This facility, of course, can serve the function of a pre-pilot operation whereby the engineering problems associated with large-scale production can be evaluated. The ease of transition from research to plant will be seriously impaired without effective operation of such a group producing suitable material in sufficient amount for full market evaluation.

Top management must be aware of the fact that when it sets up a research laboratory, much more is required than merely the presence of a group of scientists. If top management does not provide all the necessary supporting services, the research very probably will not pay off. Furthermore, in order to maintain high morale, cooperation and effectiveness in a research laboratory, it is essential that equal recognition be given not only to the men who think of the idea first but also to the men who contribute to the engineering, market evaluation and general service technology which eventually make the project a success.

These, then, are the principal responsibilities of top management to a successful research effort. The responsible executives should recognize what they are getting into and be ready to take advantage of what comes out.

Local Management Operates

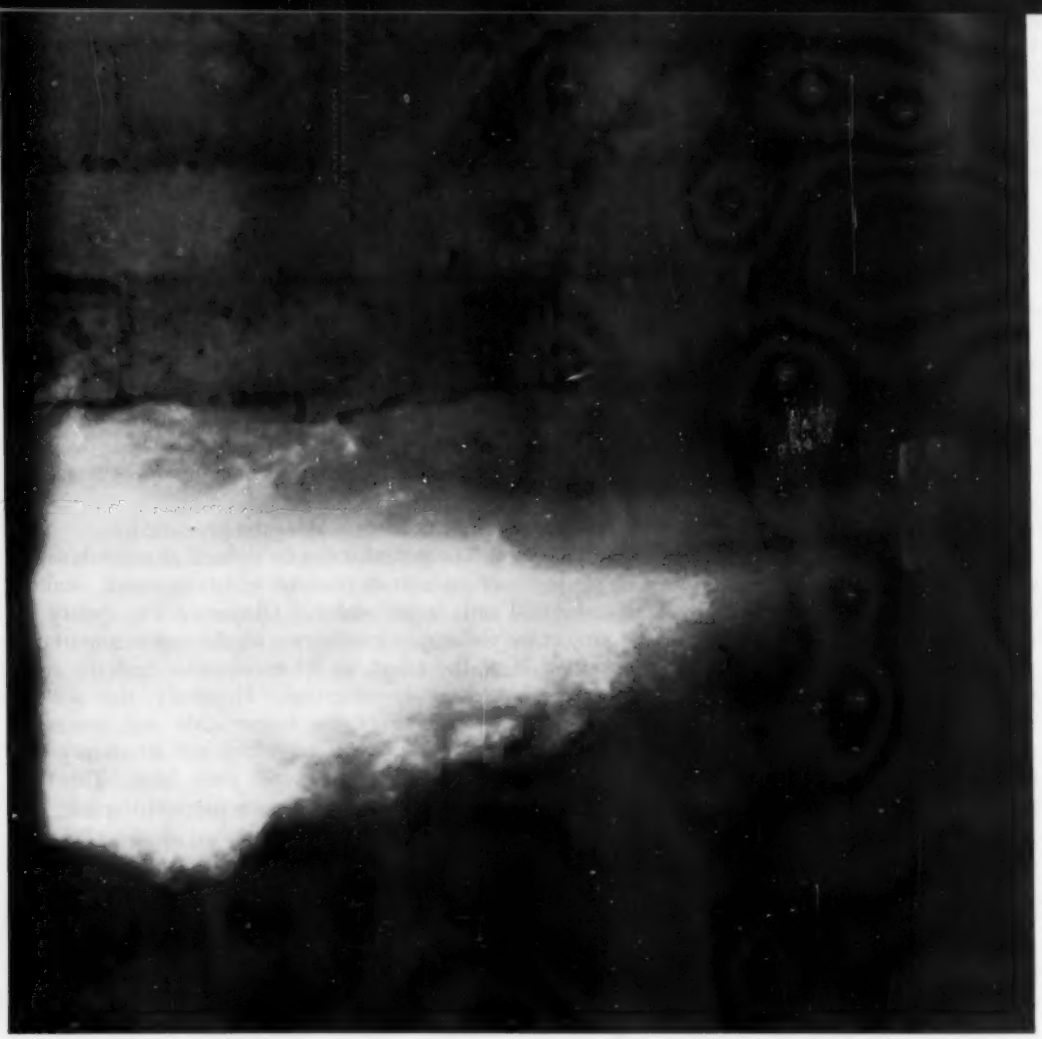
Local management (the responsible director of the particular laboratory) must make the most important decisions that can assure or impair the success of a research effort. These decisions can be made in matters of program, organization and personnel.

Let us first consider the program.

The program can be defined as a combination of projects or research efforts on small, medium and large scales. Obviously the policy or philosophy may vary with the size or importance of the effort, so let us consider first the small pioneer investigation. Hopefully, this will be the source of the larger scale and successful research projects on which the laboratory will be working two to seven years later. This type of original work based on original thinking can come from any one member of the staff and must be encouraged regardless of the urgency of current large-scale effort. The laboratory manager is under obligation to himself as well as to the top executives to see that new ideas, new products and new concepts are forthcoming in a steady stream. Hence he must make positive provision for their initiation.

In one laboratory which I know about, in order to encourage any staff man to explore any new ideas he might have, each individual was authorized to spend up to a certain amount of time on any project without any questions asked except to let his section leader know what he was doing. This scheme, however, did not really accomplish as much as was desired, although it is still available for use. It turned out – as in most research work – that new ideas germinate in the minds of a few individuals, the type that are imaginative and creative. Experience indicates the desirability of giving such men considerable freedom of operation, separating them from the more routine operations of the laboratory and forming, in a sense, an integral group where ideas can be generated and tested in a preliminary manner.

Now that the program on initiating ideas and new products is functioning satisfactorily, next will arise the problem for local management to decide and that is, "Which of these various ideas offers the best promise of a good business ven-



View Inside Experimental Kiln for Studying Use of Oxygen in Steel Melting

ture?" Some ideas fit easily into the current business and perhaps only a nominal appraisal is needed, but most of them, if they conform to the definition of research set forth in the first section of this article, are going to require considerable speculation, thought and study because their ramifications are many. Here also good judgment must prevail; enough facts are seldom available at this stage to judge adversely. I would emphasize that *adverse* judgment is one thing to be feared – that a negative decision is made without adequate facts. (*A positive* decision at this point can be corrected later if things do not develop as hoped for.)

If the project at this stage – be it a product or process – is within the current or hoped-for area of interest, plans will generally be made to proceed with the next step. Here again is where local management has to plan properly, else considerable time and money can be wasted and a good idea perhaps discarded needlessly.

Assume, for instance, that the idea is a new metallic compound. Up to now it has been made in only gram or ounce quantities, but it shows promise for some special use. In all likelihood it will now be necessary to re-assign the work on this material because the inventor does not have the equipment in his department nor perhaps the aptitude to evaluate it at the next step. What are needed now are surveys of alternate methods of production, looking for the optimum one; preliminary studies of engineering problems that will be encountered in its production; production of a sufficient quantity for field testing; active follow-up on the field testing, not only in the indicated field but also in other less obvious fields. From these tests will be learned whether the properties, characteristics, costs and other essential features of a commercial product are as hoped for, or if they need some modification such as grain size, purity, color, and so on.

The guiding philosophy of laboratory management all through this phase must be that the information gathered is as accurate as possible, is as wide as possible and embraces all the possible markets, is practical in the engineering sense, but above all, is *reliable*. It is the responsibility of local management to learn as much as possible during this low-cost phase of a commercial development.

If, while the product is in this phase, local management keeps top management well informed about the project, its significance and promise, through progress reports, management-research meetings (and perhaps special project presentations) and furthermore if the project lives up to expectations, then the decision concerning the next step into pilot-plant or large scale production is practically determined. The only remaining responsibility of research management is then to see that all data and other information are properly and adequately transmitted.

Other local management responsibilities include *(a)* being sure that all who could help are kept up-to-date on the technology, engineering, and uses of a current project; *(b)* being sure that experience already available in the laboratory or other units of the company is brought to bear; *(c)* being sure that library, patent and other information becomes automatically available to any project leaders; and *(d)* fostering an atmosphere wherein each staff member feels he is a part of the team. All of this can, of course, best be brought about by organization and planning.

The laboratories with which I am most familiar make free use of the committee system. One or more committees is set up for each project which is large enough to justify them. These committees are composed of the project leader, most of the technical men on the project, and appropriate specialists from other departments. (In passing, I will point out that here is a good place to introduce your idea men.) The committees periodically review the progress of work, criticize or comment on such phases as are lagging and obviously in need of discussion, and in general serve as technical monitors.

Another important provision that must be made if the laboratory personnel (particularly at the internal directing level) is to be able to appraise the performance properly and thereby guide their projects is for the group managers, or those directly responsible for projects, to know what charges have been made against the project and a reasonable breakdown of these items. This financial information will let the project leader know how he is conforming to his budget, whether excessive charges are creeping into his account, and whether he is working as hard on the job as was intended. It also has the very important value of making him feel a real responsibility not only for the technical success but for the fiscal soundness of his work.

Individual Scientist a Team Member

Finally we should consider the very important matter: "How can the individual worker best fit into a research project so as to assure its success?" This is in large measure the crux of the matter because no matter how well the laboratory is equipped, organized, and supplied with all the supplementary facilities that general experience and theory call for, no really successful and integrated effort can succeed unless the individual scientists, technical men, and technicians work wholeheartedly toward the desired end. The individual must, in the main, lose his individuality and really act as a member of the team.

Now this isn't always easy for a scientist who has become something of an expert in his field or for a technical man who already has a reputation in an area. Nor is it always easy for management to convince these men that their best contribution can be to a group effort rather than as a lone operator. The natural desire of people with specialized training or aptitudes is to gain recognition. This can best be achieved by either increased pay or a distinctive title. Obviously, a combination of both is most likely to encourage the man but nevertheless the use of a distinctive title is very important. By this means it is possible to indicate to others that such a man has and very satisfactorily fills a unique position in the laboratory. Therefore, he will be respected for that position. The importance of proper titles must not be overlooked in considering the personnel relationships in a research laboratory.

In conclusion, success in research depends not on the construction of glamorous laboratories but rather on positive actions and policies on the part of top and local management in choosing and planning projects, critically reviewing progress from the technical and economic viewpoints, developing a team spirit among the individual scientists, and adequately commercializing the results of research. Improper recognition of any of these responsibilities may easily lead to unprofitable research activity.

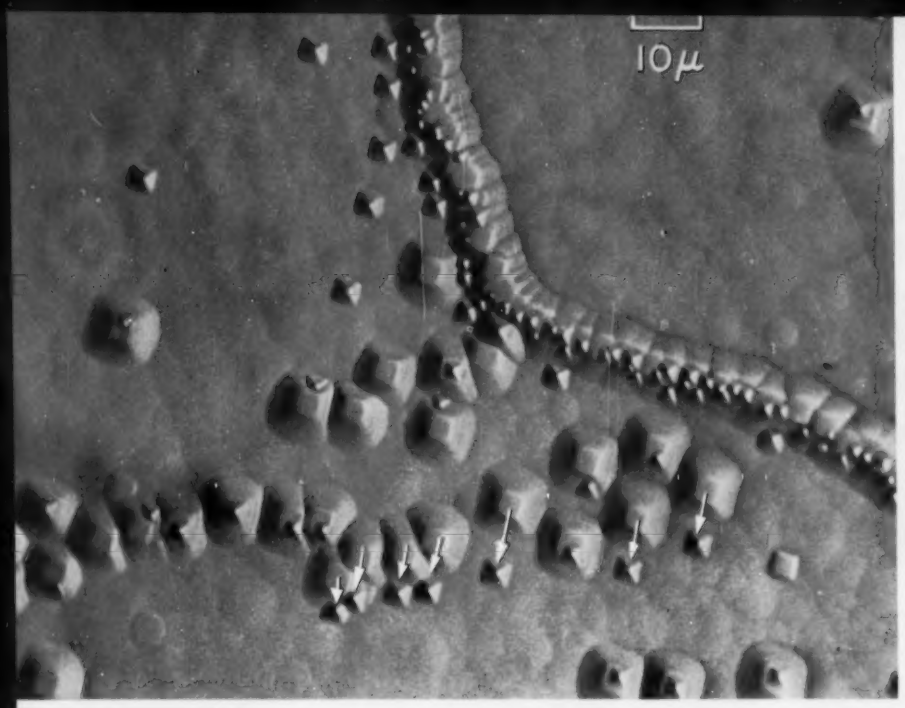


Fig. 1 – Movement of Dislocations During Annealing. The crystal of lithium fluoride was etched, annealed 16 hr. at 400° C., then re-etched lightly. The pits with flat bottoms show where the dislocations were before the anneal; the pointed pits show the dislocation position after the anneal. Some before-and-after positions are shown by arrows. Across the upper right corner is a subgrain boundary that moved slightly during the anneal

Movement of Dislocations

*By JOHN J. GILMAN and WILLIAM G. JOHNSTON**

IT IS NOW POSSIBLE to observe dislocation motions in crystals. Although the illustrations in this brief note are of nonmetallic crystals of lithium fluoride, they show by analogy how dislocations probably move in metal crystals.

The experiment is simplified because of the highly specific way in which lithium fluoride crystals can be etched. Lithium fluoride has the same crystal structure as common salt (NaCl), and like salt it can be readily cleaved along its cube (100) planes. Specimens prepared by cleavage have flat mirror-like surfaces. When these surfaces of lithium fluoride are etched in 1 part of concentrated HF, 1 part glacial acetic and a pinch of FeF_3, they are not attacked uniformly. Almost no attack occurs except where a line of dislocations intersects the surface. At these dislocation sites, small pits grow with a pyramidal shape. Examples of this phenomenon may be seen in the accompanying photographs.

*Research Laboratories, General Electric Co., The Knolls, Schenectady, N.Y. The micros won honorable mention in the last Metallographic Exhibit.

The etching attack is so sensitive to the presence of dislocations that, if the dislocation moves away from the bottom of the etch-pit, the pit immediately stops getting any deeper although it continues to grow sidewise. Thus it becomes "flat-bottomed" or truncated and can be distinguished easily from the pointed pits at places where dislocations are still present. Thus one can see the "before" and "after" positions of dislocations which have moved.

Dislocations can move in two ways. They can "glide" easily if a shear stress is applied to them, and at somewhat elevated temperatures they can also "climb" when vacancies diffuse toward or away from them. Both of these processes are illustrated in the photographs.

The photographs were made with a metallograph using oblique reflected light. Transmitted light is not suitable for observing the pits. For work at high magnifications, the contrast can be increased by evaporating a thin film of silver onto an etched surface.

There is much cogent evidence that the pits represent dislocations. Perhaps the most con-

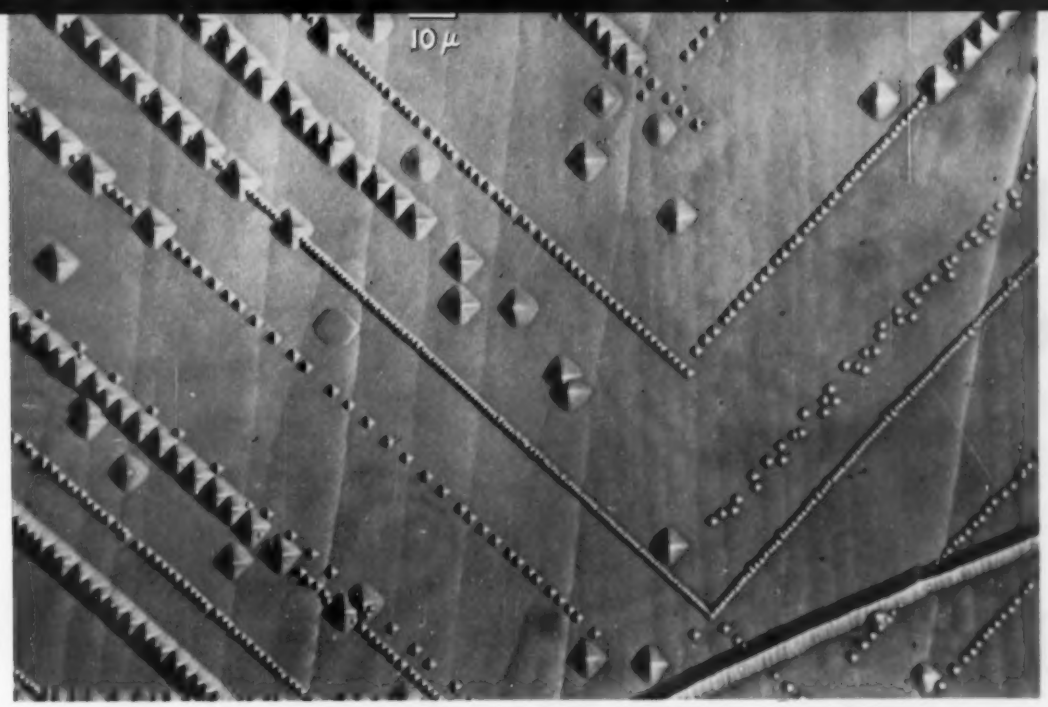
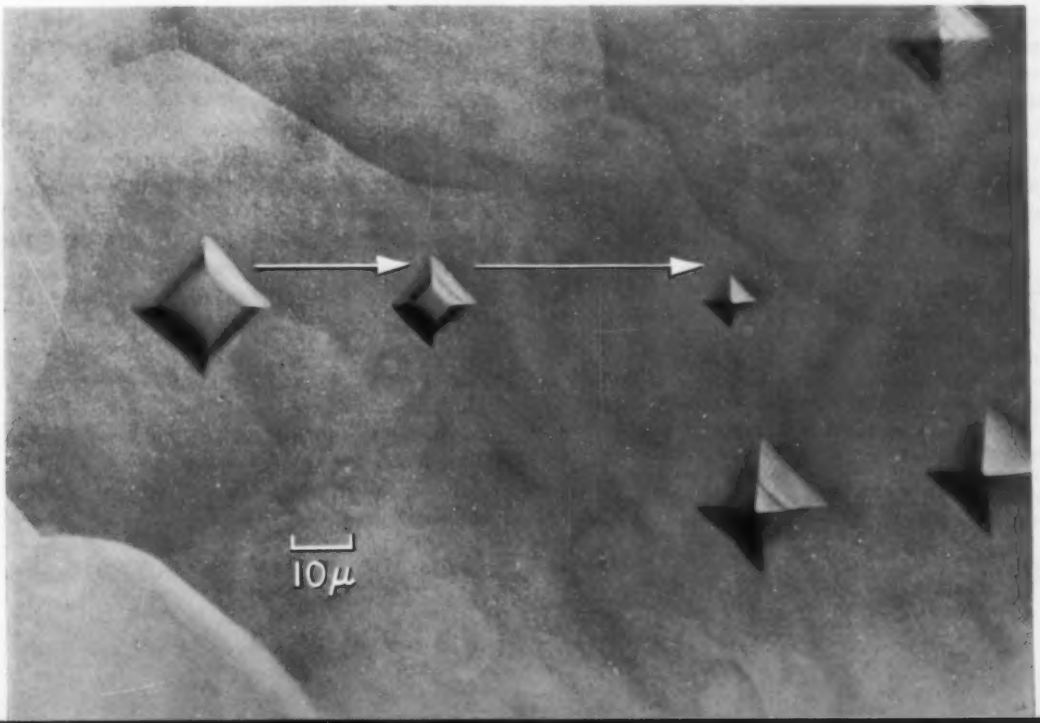


Fig. 2 – Glide of Dislocations During Plastic Bending. The crystal was bent slightly and etched, then bent slightly more and re-etched lightly. This view looks parallel to the axis of bending, the plane of the photograph is the neutral plane, the cube (100) plane. Dislocations have glided along (110) planes toward the neutral plane from both sides

vincing reason is simply that they are found in arrays that are just what theory would predict. They are located in subgrain boundaries in as-cast crystals. They are found arrayed neatly along glide planes in deformed crystals. When a deformed crystal is annealed they disappear. In all events, the pits behave just as would be expected of dislocations. Furthermore, a dislocation is defined as a "line imperfection" in a crystal, and by etching lithium fluoride crystals very deeply, it is found that the bottoms of etching pits follow definite lines going through the crystals and hence conforming with the definition of a dislocation.

Fig. 3 – Glide of an Isolated Dislocation. Technique was as in Fig. 1, but in three successive steps. Arrows indicate the direction of motion



Cracking Tendency in Heavy High-Temperature Steam Piping

*By HENRY M. SOLDAN and CHARLES R. MAYNE**

Stabilized 18-8 (Type 347) is the conventional material for high-temperature steam service. Occasional cracks alongside welds may be avoided by using metal and welding electrodes (like 16-8-2 Cr-Ni-Mo) which have 60% reduction of area or more when cooled from 2400° F. and tested at 2300° F. (Q23p, 2-12; SS, 1-7, 9-22)

IT IS WORTHY of note that, despite much use of chomium-nickel steels in high-temperature equipment in central station service, the established grades of the A.I.S.I. Type 300 Series, such as 316, 321 and 347, were developed for the chemical industry, the latter two largely to avoid chromium depletion in metal alongside welds which had resulted in "intercrystalline embrittlement" in welded piping in certain chemical processes. None of these steels were actually developed for high-temperature steam piping.

The requirements for both welding procedures and operator qualifications for high-temperature weldments have been that the specimens meet the various tests performed at room temperature as prescribed in the A.S.M.E. Boiler Code. It requires no argument for a welding or metallurgical engineer to agree that only a ductile metal could be expected to be welded crack-free, and that considerable ductility is a prime requirement for closed metallic structures wherein the temperatures undergo considerable fluctuations. These thermal stresses are magnified in thick-walled vessels or piping, especially when made of metal with low heat conductivity, such as the Cr-Ni austenitic steels.

*Mr. Soldan is senior engineer in the Electric Engineering Dept. of Public Service Electric and Gas Co., Newark, N.J., and Mr. Mayne is metallurgist in the Development and Research Division of International Nickel Co., New York. This paper is a shortened version of a presentation at the sixth annual meeting of the Atomic Energy Commission Welding Committee at Oak Ridge, Tenn., in September 1956, entitled "The Role of Ductility as Related to Service Performance of Heavy-Wall Austenitic Steel Pipe Welds", and it appears in full (with discussion) in *Welding Journal* for March 1957.

Nevertheless, the Boiler Code defines the relationship between ductility of the deposited weld and the parent metal only by certain "essential variables" which have proven to be inadequate to assure satisfactory service performance of austenitic welds in high-temperature service. For example, when a tensile specimen containing a weld at its middle broke outside of the weld, the test was considered highly satisfactory since it established the fact that the weld was stronger than the parent metal.

It seems probable that in obtaining the above results we often imposed stresses in the weld affected zones in the adjacent parent metal which approach the yield point which – for other than ferritic steels in operation at lower temperatures – might result in failure unless the joint had sufficient capability to flow and contract in cross sectional area during solidification or heat treatment.

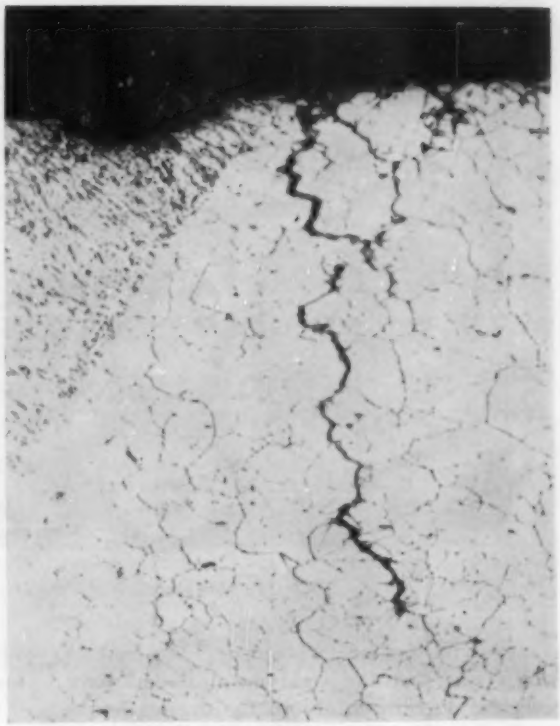


Fig. 1 – Typical Crack in the Outside of a Heavy-Walled Pipe of Type 347 Austenitic Steel in the Heat Affected Zone Alongside the Weld. × *100*

Cracks in Type 347

Because of its good creep and stress-rupture properties, coupled with comparative freedom from intergranular carbide precipitation, A.I.S.I. Type 347 (18-8 Cr-Ni, stabilized with Cb) was the original choice for use in heavy-wall piping. Therefore experience on the use of stainless steel for power generation is practically limited to Type 347.

From the amount of publicity given to the failure of some of the welded joints, one might assume that all welded joints in heavy-wall Type 347 stainless steel pipe had failed or were on the verge of failure. The real facts are that only a small percentage of these welded joints have cracked either during welding or after service. These cracks have been primarily confined to the parent metal very close to the weld in the outer third of the pipe wall (which is stressed in tension from the localized thermal expansions and contractions of the welding operation). A typical crack is shown at 100 diameters enlargement in Fig. 1; it appears to have started at the outer surface and progressed at right angles to the surface, following the grain boundaries. While no catastrophic failures have occurred in service, this is probably due to the considerable time required for these cracks to propagate through the wall under the reversal of stresses in a high-temperature piping system and result in a leak. It has often been difficult to repair such a crack without extending it further back into the parent metal. Experimental repairs have been made successfully with more ductile material from Type 308 electrodes (20-10 Cr-Ni, not stabilized). Prescribed stress levels in the present Boiler Code for Type 308 for complete pipe-line welds would require excessively heavy wall thicknesses.

Without attempting to review the enormous amount of work which has been done on the problem of weld cracking or to discuss the various theories as to the cause, we feel that much progress can be made if attention is concentrated on ductility of the metal at high temperatures. This is evidenced by the new "hot ductility tests" devised by E. F. Nippes and W. F. Savage at Rensselaer Polytechnic Institute. Furthermore, O. R. Carpenter and R. D. Wylie of Babcock and Wilcox Co. made available in the spring of 1955 a new electrode known as Croloy 16-8-2 (16% Cr, 8% Ni, 2% Mo) and described at length in *Metal Progress* for November 1956. This resulted from a considerable

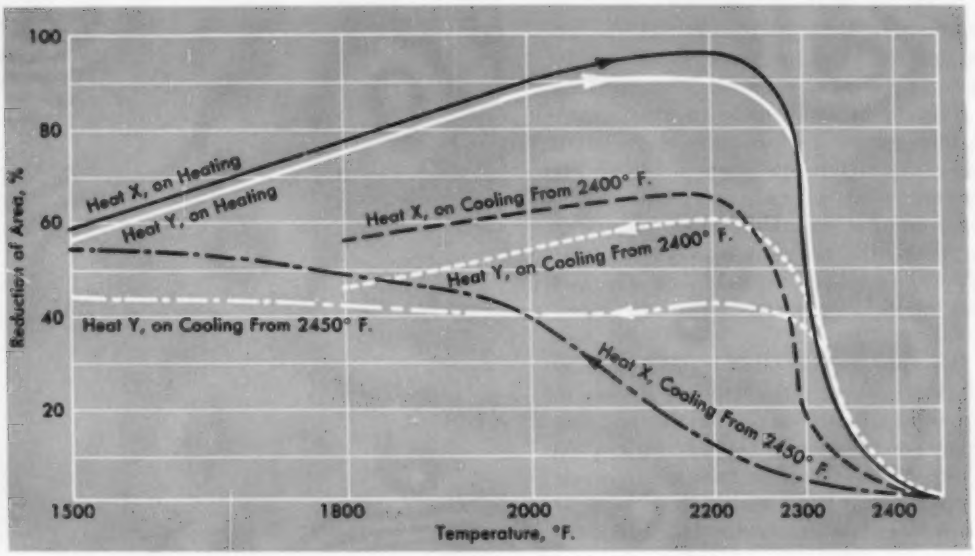


Fig. 2 – Hot Ductility of Two Heats of Type 347 Stainless

study of the factors involved, not the least of which was that the weld metal should have sufficient ductility to absorb the stresses resulting from welding without imposing more stress upon the adjacent parent metal in the hot adjacent zone than it was able to take – particularly if the material were hot short, or if notches were present due to sudden change in cross section, or if considerable restraint were present in the connection due to improper design.

Numerous tests and service applications by ourselves and others appear to have verified the fact that successful new and repair welds with 16-8-2 electrodes have been made in Type 347 piping which was known to be crack sensitive when welded with the best of the controlled low-ferrite electrodes known to us.

One specific and typical case will be cited. In making up Type 347 heavy-wall piping connections, 10.5-in. OD × 1⅝-in. wall, between the throttle valves and the steam chests of a large central station unit, three of the welds were readily made with controlled low-ferrite Type 347 electrodes and solution heat treated without requiring any repairs, while three other similar weldments cracked in the metal adjacent to the heat affected zone of the parent metal. The latter three welds were then remade with the new 16-8-2 electrodes without any cracking difficulty whatsoever.

Table I – Service Material Tested in Fig. 4

Sample	Steel	Kind	Size		Service		Hot Ductility *(a)*	Performance
			O.D.	Wall	Hours	Temp., °F.		
A (S-9)	347	Wrought pipe	6.625	0.718	22,720	1050	72	Good
B (S-5)	347	Wrought pipe	6.625	0.718	11,850	1050	13	Broke in service
S-16	347	Forged valve	12	2.25	9,170	1050	19	Broke in service *(d)*
B-11	347	Wrought pipe *(b)*	10.5	1.580	7,000	1100	59	Good
K-9	347	Forged pipe *(b)*	9.75	1.625	26,000	1100	39	Varies *(e)*
S-42	347	Forging	7	1.125	41,000	1050	10	Crack sensitive
S-34	321	Wrought pipe	6.625	0.718	20,000	1050	23 *(c)*	Crack sensitive

(a) Reduction of area, %, when broken at 2300 °F. after cooling from 2400 °F.
(b) From rings cut from pipe in service.
(c) Broken at 2300 °F. after cooling from 2450 °F.
(d) Gave considerable trouble in initial fabrication.
(e) Good at circumferential welds; crack sensitive at support lugs.

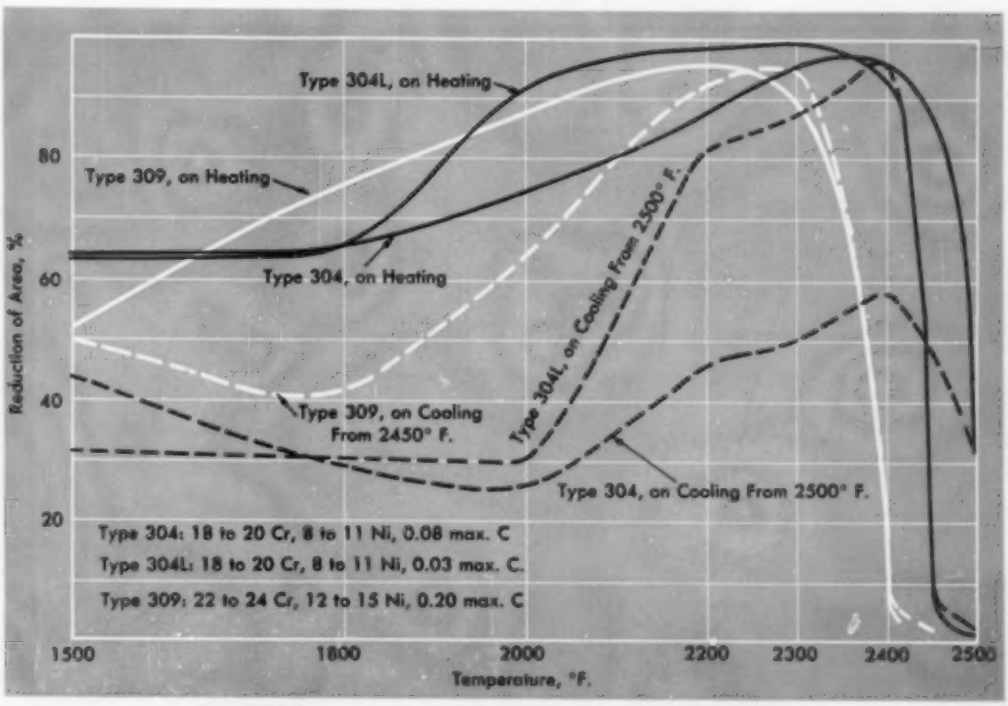
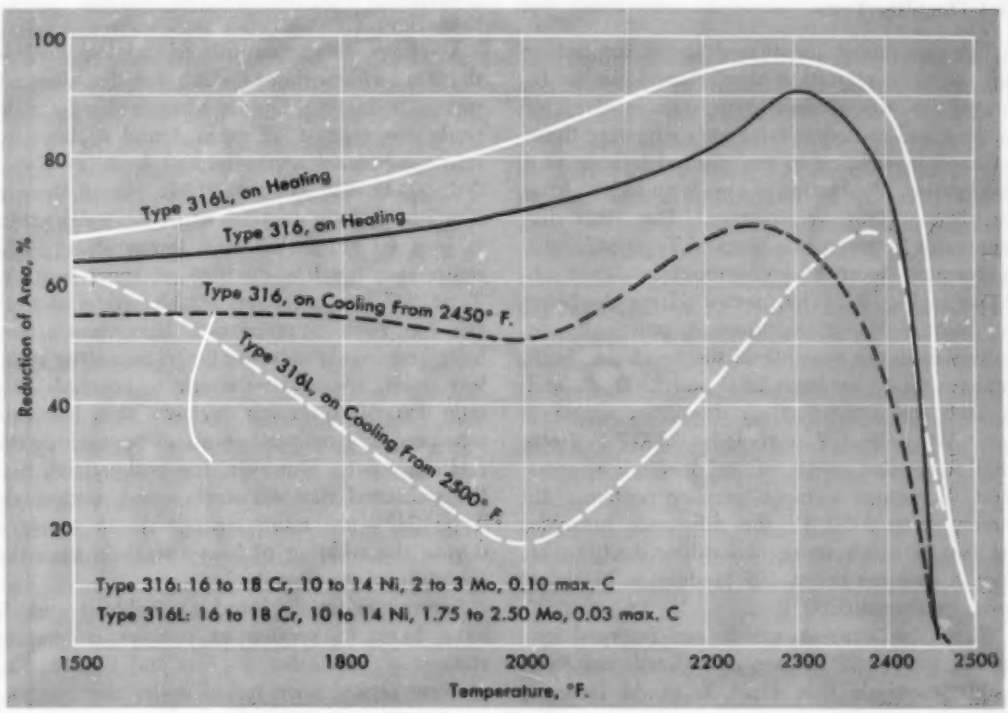

Type 304L, on Heating
Type 309, on Heating
Type 304, on Heating
Type 304L, on Cooling From 2500° F.
Type 309, on Cooling From 2450° F.
Type 304, on Cooling From 2500° F.
Type 304: 18 to 20 Cr, 8 to 11 Ni, 0.08 max. C
Type 304L: 18 to 20 Cr, 8 to 11 Ni, 0.03 max. C.
Type 309: 22 to 24 Cr, 12 to 15 Ni, 0.20 max. C
Reduction of Area, %
80
60
40
20
1500
1800
2000
2200
2300
2400
2500
Temperature, °F.

Fig. 3 (Above) and Fig. 4 (Below) Indicate That Unstabilized Chromium-Nickel Austenitic Steels Recover Ductility Rapidly When Cooling From Near-Melting Temperatures



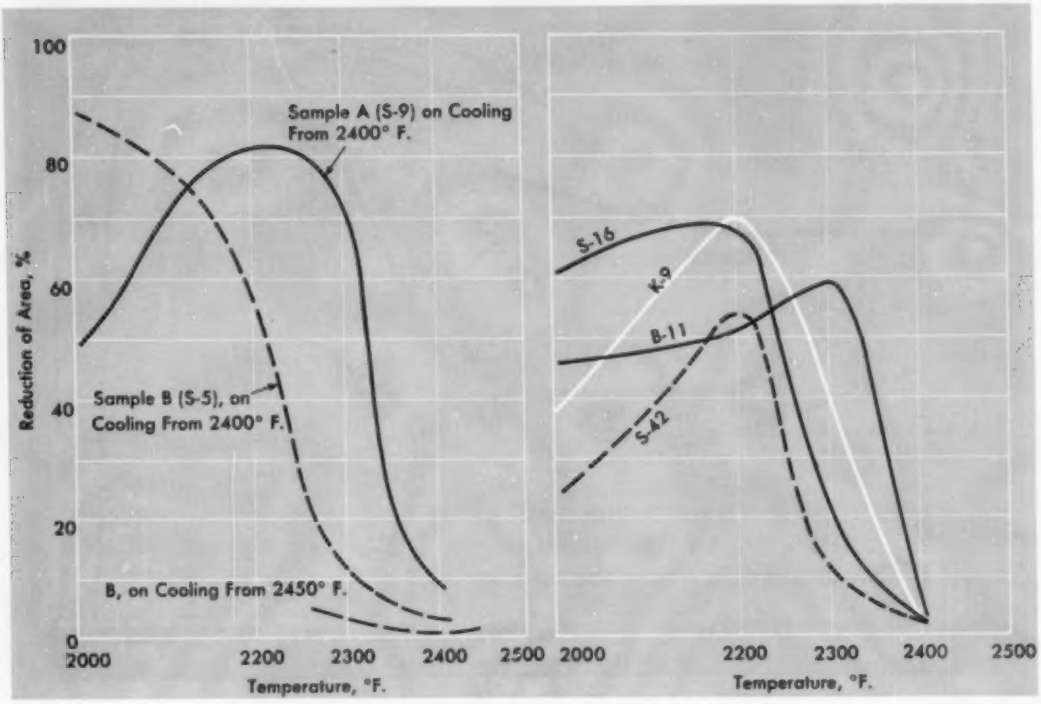


Fig. 5 – Hot Ductility Curves on Cooling Samples of Type 347 Steels Taken From Service, as Described in Table I

Hot Ductility Tests

The equipment mentioned above for testing hot ductility permits a tensile specimen to be heated to any desired temperature short of melting and cooled at rates approximating those incurred in welding to any desired temperature and broken. Reduction of area is an index of the ductility at that temperature. How this discriminates between two heats of Type 347, each conforming to A.I.S.I. composition limits, is shown in Fig. 2. When tested during the heating part of the cycle, there is practically no difference in the ductility of the two heats; both increase up to between 2200 and 2300° F., and at 2400 and 2450° F. their ductilities are very low. When heat Y is cooled to 2300° F. from 2400 it regains much of its dutility, whereas Heat X regains a much smaller portion. In cooling from 2450° F., the difference between the two is much more noticeable; ductility of Heat X remains below 10% (reduction in area) down to almost 2200° F.

When the stresses which are imposed on cooling from 2450° F. are considered, one can readily conclude that Heat X would have a greater tendency for cracking during welding than Heat Y.

We have tested *unstabilized* stainless steels of the 300 series without finding one that does not regain its ductility rapidly when cooled from the peak temperature. Figures 3 and 4 show the results obtained on individual heats of Types 304, 304 L, 309, 316 and 316 L. In all there is a rapid regain in ductility when the temperature is lowered from the peak temperature. The reason for the low ductility of some heats of Type 347 has not been established, and until this has been done or until many more tests have been made on other Cr-Ni austenitic stainless steels, it would be wrong to conclude that *only* Type 347 regains ductility at a low rate when cooled from temperatures approaching the melting point. However, the authors feel that the stabilized stainless steels – and particularly Type 347 – are more susceptible to cracking during the welding of heavy sections than the unstabilized stainless steels.

Several materials listed in Table I, which have been in service at various generating stations of Public Service Gas and Electric Co. of New Jersey, were tested under the sponsor-

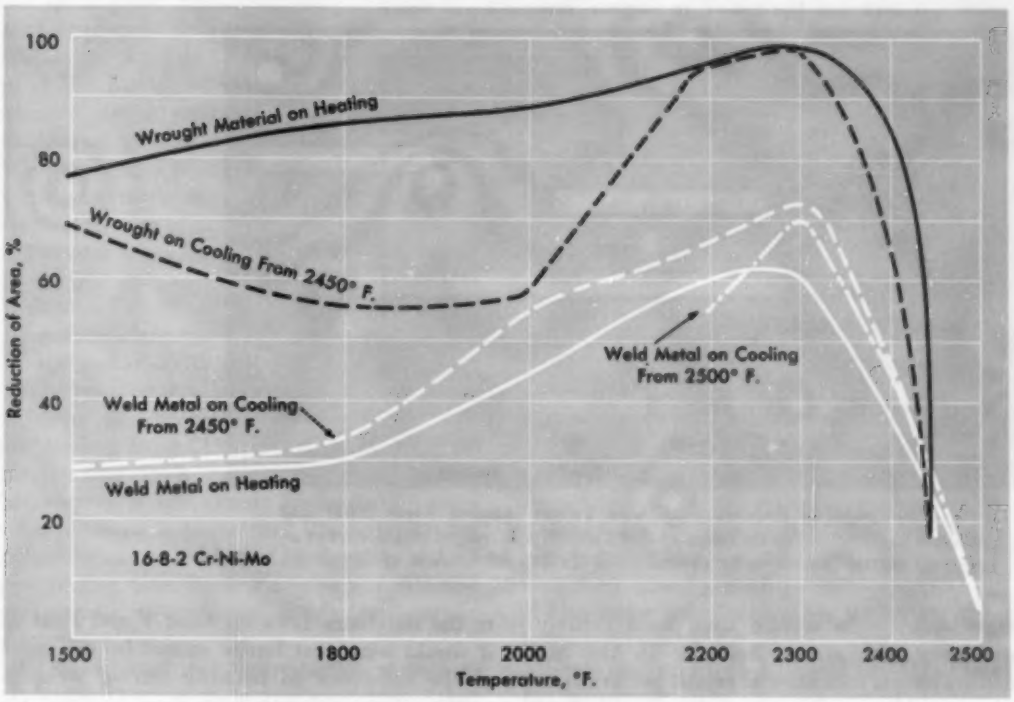


Fig. 6 – 16-8-2 Cr-Ni-Mo, Both Wrought and All-Weld Metal Samples, Recovers Ductility Rapidly on Cooling from 2450 or 2500° F.

ship of the International Nickel Co. to determine whether or not the hot ductility tests would coincide with observed performance. The results are shown in Fig. 5. (The curves are not as complete as the previous ones because enough specimens were not available). It is evident that materials A (S-9) and B-11 behave quite similarly to Heat Y, the better of the two in Fig. 2; Table I also shows that these did not crack during fabrication or service. Materials B (S-5), S-16 and S-42 behave similarly to Heat X of Fig. 2, and Table I shows that cracking was encountered in these materials.

It is interesting to see in Fig. 6, which shows the results of hot ductility tests on the Babcock and Wilcox 16-8-2, both wrought material and all-weld metal. When compared with the satisfactory performance of 16-8-2 in welds, the results are consistent.

Accordingly it is logical to predict that the hot ductility test of Rensselaer Polytechnic Institute may indicate the tendency of materials to crack during welding. Figure 7 shows the range of the reduction of area as determined during the hot ductility tests for several alloys considered for high-temperature service.

Base Materials

A group representing the metallurgical engineering staffs of nickel and steel producers, turbine and boiler manufacturers and pipe fabricators associated with Public Service was brought together in 1955 to discuss ways of improving service performance of austenitic weldments. Their discussions indicated that the best choice, at this time, for heavy-wall high-temperature steam piping is A.I.S.I. Type 316 (16% Cr, 13% Ni, 2% Mo). This appears to have good high-temperature characteristics and behaves in a superior manner in the hot ductility tests. It is currently considered to be a stronger material for high-temperature service than others in the A.I.S.I. 300 Series and is so accredited in the A.S.M.E. Boiler Code. Type 308, while appearing suitable from a ductility standpoint, is legislated against by the lower allowable "S" values appearing in the Boiler Code. However, there is a strong body of opinion that the entire series should be reappraised as to the effects of heat treatment and grain size control.

While the vast majority of welds made in Type 347 austenitic steel piping now in high-

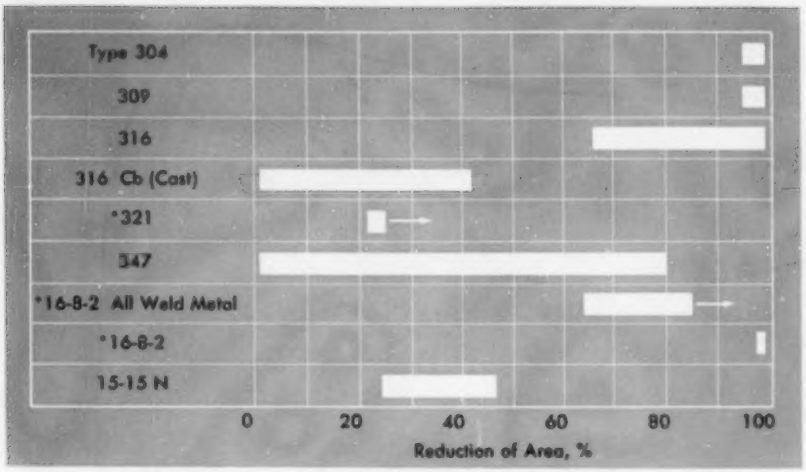


Fig. 7 – Range of Reduction of Area Values (Cooled From 2400 and Broken at 2300° F.) as an Index of Hot Ductility. Wrought metal, except as shown. Starred items were cooled from 2450 and broken at 2300° F.

temperature steam service have been entirely satisfactory, the erratic behavior in the hot ductility tests is indicative of erratic performance in both welding and service when a poor heat of this material is encountered.

Metallurgical Examination

The results of our limited amount of laboratory work to date follow:

It has been noted that the specimens exhibiting poor ductility (even the good ones at elevated temperatures) failed intergranularly, which is not unexpected for brittle failure. It is possible that the brittle failure is due to the formation of some intergranular compound. Additional work is under way with the electron microscope, X-ray diffraction and similar apparatus to determine the existence of such grain boundary constituents.

The microstructure of the good Heat Y, after heating to 2400° F. and cooling and breaking at 2300° F., contains considerable amounts of ferrite while the bad Heat X contains practically none. (This was checked by magnegage readings). This might be interpreted as meaning ferrite is necessary in the base metal to insure freedom from cracking during the welding of heavy sections. However, a comparison of the structure of materials A (S-9) and B (S-5), when tested after similar treatment, shows that neither of these contain any appreciable amount of ferrite. Since the difference between the behavior of A (S-9) and B (S-5) is quite similar to the difference between Heat Y and Heat X, it would seem that ferrite cannot be the cause of the difference in behavior during welding.

These four materials have been analysed for differences in chemical constituents (Table II), and the cause of the ferrite in Heat Y is due primarily to the lower nickel content. There is practically no difference at all in the trace elements: Spectrographic results showed "Trace" to "Very Slight Trace" for B, Ca, Mg, Cu, Mo, V, Zn, Zr, Ba, Ce, and W. The following elements were "Not Found": Pb, Li, Sb, As, Be, Bi and La.

Correlation With Service

If correlation of service performance with the hot ductility tests on the same material is confirmed after more complete data are obtained, the next problem would be to procure material with hot ductility suitable for satisfactory weldability and service performance. Obviously, steel mills at this time would be reluctant to reject finished tubes because of low hot ductility. This means that this property must be determined early in the production stage – preferably on specimens taken from the ingots or blooms.

We do not know as yet if the hot ductility remains consistent throughout manufacturing, and to obtain data on this, we have secured several samples representing various stages of the manufacture of A.I.S.I. Type 316 piping intended for the main steam piping at No. 2 Unit, Linden Generating Station. If further data on this and

other types prove consistent, we expect to propose an appropriate revision to A.S.T.M. Specification A-376 for high-temperature austenitic piping, such as: "The reduction of area of a specimen of the ingot from which the piping will be made shall show a reduction of area of not less than . . . per cent when broken at . . . degrees F. upon cooling from . . . degrees F."

The Rensselaer tests indicate that the reduction in area may often be considerably lower when specimens are broken at 2300 upon cooling from 2450° F. than upon cooling from 2400. The cause of this phenomenon is not clearly understood. Data so far obtained indicate that the susceptibility to cracking can be evaluated by ductility at 2300 upon cooling from 2400° F.; values of 60% and over appear to indicate satisfactory service performance.

We have found that the reduction of area in hot ductility tests of transverse specimens, taken from narrow test rings, was lower than in longitudinal specimens taken from longer sections. We believe that this could account for the variable performance indicated for item K-9 in Table I, the tests of which were made on transverse specimens, and in which the butt welds have given excellent performance while support lug attachments have invariably caused severe cracking of the heavy-wall piping. This leads us to conclude that the safest practice is to avoid welded support lugs unless sufficient flexibility is provided in the design to permit free expansion of all parts.

There is no indication that a material displaying good hot ductility during initial fabrication will depreciate in this respect while in service. See, for example, material A (S-9) of Table I, which had 72% reduction of area at 2300° F. after 22,720 hr. of service at 1050° F.

Table II – Chemical Analysis of Two Good and Two Bad Heats of Type 347

	Heat X, Bad	Heat Y, Good	Heat A (S-9), Good	Heat B (S-5), Bad
Carbon	0.06%	0.06%	0.052%	0.06%
Nickel	12.33	9.79	12.82	12.84
Chromium	20.09	20.14	—	—
Columbium	0.78	0.82	0.82	0.83
Silicon	—	—	0.54	0.54
Manganese	—	—	1.64	1.64
Nitrogen	0.024	0.009	0.020	0.027
Phosphorus	—	—	0.007	0.007
Sulphur	—	—	0.007	0.006
Aluminum	0.018	<0.01	0.025	0.033
Titanium	0.14	0.14	0.053	0.037
Antimony	0.022	0.021	0.003	0.007

Further Studies

We plan to obtain additional test materials from sections of piping with known crack sensitivity and poor service performance as soon as these materials are replaced in service. We hope that such information will support the limited data now available and that the hot ductility tests will aid in the selection of suitable materials for high-temperature service.

Other utilities and associated companies are encouraged to obtain material representing the various heats of main steam piping from which hot ductility tests can be made and compared with their actual service performance.

Also under consideration are the effects of the following variables:

Grain size, on which a limited amount of work has been done.

Melting Practice – When sufficient amounts of a poor material become available, some of this will be remelted in vacuum to determine whether or not this will remove the cause of crack sensitivity.

Forging Practice – If a heat shows poor ductility in the ingot, it is proposed that the effect of variable amounts of forging should be investigated to determine how much hot work is necessary to remove or reduce sensitivity to cracking after welding.

Chemistry – We plan to study the effect not only of minor elements, such as nitrogen, but also the effect of the ratio between carbon and stabilizing elements.

A large portion of this work will be sponsored by the International Nickel Co., working in close contact with the E.E.I.-A.S.T.M.-A.S.M.E. Task Force SP-5, which is currently investigating this subject.

While the hot ductility test may separate the good from the bad, and while the use of 16-8-2 welding rod may facilitate the welding of at least some of the crack sensitive material, the paramount question still remains: "Why are some heats of austenitic stainless steel sensitive to cracking while others of similar composition are insensitive to the same type of failure under identical conditions?"

Fig. 1 – Failure of Type I Which Occurs During Driving of the Pile

Brittle Fracture of Sheet Piling

*By W. A. MORGAN and R. C. A. THURSTON**

Sheet piling is usually rolled of structural steel which can meet moderate requirements. While service records are good, several failures in Canadian waters indicate that its transition temperature, where fatigue cracks or corrosion pits lead to catastrophic brittle fracture, is well above the water temperature. (Q26s, T26; AY, CN)

A GREAT DEAL of work has been reported in the technical literature on brittle fracture at low temperature, particularly in ship plate. Attention has also been drawn to similar failures in bridges, tanks and other structures than ships. The topic has been covered in an excellent and comprehensive review article by M. E. Shank, issued serially in *Metal Progress* issues of September and October 1954 and June 1955.

In all the publications, however, no reference has been made to brittle fracture of steel sheet piling. In Canada numerous examples of such failures have been examined, and the service behavior correlated with laboratory tests. The present article is intended to summarize these investigations.

Types of Failures

The failures observed in the sheet piling examined over a period of eight years can be divided into three main types:

Type I – Driving failures, where fracture propagated from the flame-cut handling hole (Fig. 1).

Type II – Failures during service, where fracture propagated from flame-cut tie-rod holes, drain holes or bolt holes (Fig. 2). This also includes fractures initiated at defective welds and at arc strikes.

Type III – Brittle fractures initiated by fatigue cracks (Fig. 3).

The majority of failures encountered fell into the first two groups, Types I and II. After the rust had been removed, the samples usually showed characteristics of brittle fracture – that is, no reduction in thickness, little or no shear lip, and a marked herringbone pattern pointing back towards the origin. All fracture surfaces were at right angles to the surface.

Type I failures were fairly extensive, usually several feet long, more or less parallel to the longitudinal axis of the piling, veering off toward one side of the web at the end. Type II failures were less extensive and showed no particular

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Table I – Data on the Alloy Steels

	A	B	C	D	E
Composition					
Carbon	0.40	0.33	0.28	0.37	0.29
Manganese	0.90	0.75	0.80	0.80	0.86
Silicon	0.17	0.19	0.14	0.12	0.16
Sulphur	0.045	0.031	0.028	0.023	0.027
Phosphorus	0.037	0.010	0.022	0.011	0.018
Chromium	0.80	0.55	0.50	0.51	0.49
Nickel	—	0.064	0.03	0.02	—
Copper	0.06	0.44	0.09	0.42	0.42
Mn÷C ratio	2.3	2.3	2.9	2.2	3.0
Web thickness, in.	1.0	0.875	0.875	0.875	0.375
Tensile tests					
Yield*	70,800	68,400	40,200	70,000	66,000
Ultimate	121,500	100,500	99,600	110,900	97,000
Elongation in 2 in.	15.5	21.5	24.0	19.0	13.5†
Transition temperature					
At 15 ft-lb. energy	—	122	97	176	50
Average energy‡	—	118	127	140	68
At 50% shear	—	162	145	221	95
Energy absorbed					
At 32° F.	3	4.5	9	3	12
At 75° F.	4	6	9	6	22

*0.2% offset †Fracture near gage mark

‡Transition temperature for average energy is the temperature corresponding to the mid-way value between maximum and minimum impact energy absorption.

preference for any specific direction. Type III failures were essentially transverse to the direction of rolling, and propagated completely across the section.

Metallurgical Examination

The samples examined included a variety of section shapes from different manufacturers, and varied in thickness at the web from about ⅜ to 1 in. Most of the steels were plain medium carbon analyses, but five contained chromium and some of them copper additions. Both bessemer and openhearth steelmaking processes are represented. Of the data obtained from the chemical, metallurgical and mechanical tests, only the more significant results will be summarized in this article.

Tables I to IV give the chemical analyses of the 21 broken piles which we examined, together with the tensile properties and data on the transition temperatures as estimated by impact tests.

Tensile Tests – Three types of tensile specimens were used, primarily depending on the thickness of the web. As noted in the tables, 0.505-in. round specimens with 2-in. gage length were cut from the piles with thick enough webs. In the others, flat specimens were cut, 1½ in. wide and either 8-in. or 4-in. gage length, the thickness being that of the web.

The fractured surfaces of the tensile specimens all showed ductile shear fractures with the exception of samples S and U, which had approximately 50% and 25% cleavage failure, respectively. Adjacent to these areas were surface defects in the piling which were probably the result of pitting corrosion. The brittle facets may therefore have been produced by these pits acting as notches. To check this possibility, further tensile tests were made on similar test pieces with surfaces ground to remove the surface defects. The reproducibility of test results on the ground specimens was very much better than on the as-received samples, and no evidence of cleavage fracture was visible. The averages of results are:

	Pile S		Pile U	
	Rough	Ground	Rough	Ground
Yield stress	57,450	51,500	57,450	51,550
Ultimate	87,950	89,300	88,750	86,700
Elong. in 8 in., %	13.5	23.0	12.5	24.5

Fig. 2 – Failure of Type II, Propagating From a Flame-Cut Drain Hole

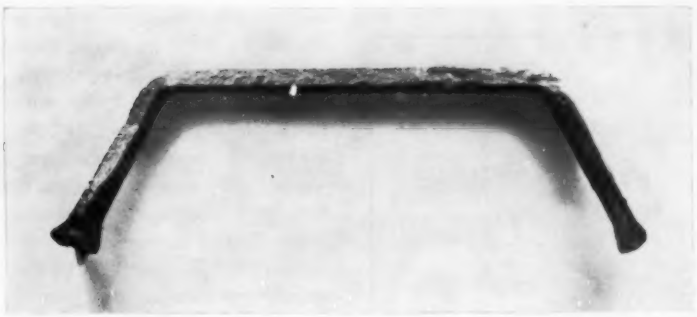


Fig. 3 – Failure of Type III, Showing the Chevron Pattern of a Brittle Failure Initiated by a Fatigue Crack

It seems, therefore, that the pits in the surface caused a sufficient local triaxial stress condition to produce partially brittle failure at low elongation in a standard tensile test at 75° F.

Impact Tests – The thickness of the web of the piling determined whether standard 0.394-in. square or substandard Charpy V-notch samples were used. Since the prevailing direction of the crack was longitudinal, all test pieces were cut with their length in the transverse direction, and notched at right angles to the original surface. The width of the substandard specimens was maintained at 0.325 in. and the V-notch was machined in this face; the area below the notch was about 82.5% of the standard. Notches were checked on an optical comparator.

Tests in triplicate were carried out at temperatures ranging from −40° F. to +300° F. Specimens were chilled (or heated) for 30 min. in a mixture of solid CO_2 and acetone or in a constant temperature oil bath). Figures 4 to 7 summarize the results, and from them are scaled the values of the transition temperatures given in the tables. The criteria selected are the ones most frequently adopted – 15 ft-lb. energy absorbed, average energy absorbed, and 50% shear in the fracture.

Table II – Data on Carbon Steels of Superior Quality

	F	G	H	I
Composition				
Carbon	0.32	0.33	0.30	0.33
Manganese	0.75	0.78	0.72	0.87
Silicon	0.07	0.12	0.25	0.11
Sulphur	0.033	0.026	0.019	0.019
Phosphorus	0.032	0.020	0.014	0.011
Chromium	0.04	0.04	0.05	0.06
Nickel	Tr	Tr	—	—
Copper	0.23	0.05	0.05	0.008
Mn ÷ C ratio	2.3	2.3	2.4	2.4
Web thickness, in.	0.5	0.375	0.375	0.5
Tensile tests				
Yield*	40,300	44,100	51,700	57,300
Ultimate	66,000	70,600	78,750	76,550
Elongation in 4 in.	32.0	30.7	27.2	28.8
Transition temperature				
At 15 ft-lb. energy	+ 1	− 9	+19	+19
Average energy	39	10	39	39
At 50% shear	45	16	52	57
Energy absorbed				
At 32° F.	23	23	18	18
At 75° F.	44	32	27	28

*Drop of beam

Alloy Steel

Samples A to E (Table I) are low-chromium steels, some with copper added. Impact values, as they vary with temperature, are shown in Fig. 4. Steel E, which is from a driven pile having no cracks, has the highest Mn ÷ C ratio of all the steels studied. Samples A to D cracked during driving, and failure can be attributed to low-temperature brittle fracture; cracks started at irregularly formed flame-cut handling holes at the top of the pile. Sample E showed no sign of failure even though the end of the pile had deformed considerably from blows of the driver. This may be attributed to the following factors:

1 – The handling hole was cut smoothly and round, and was considerably further from the end of the pile than in samples A, B, C, and D.

2 – The web was only ⅜ in., which resulted in finer grain size after rolling.

3 – The carbon content was lower than in A, B or D and the Mn ÷ C ratio was higher. Sample C has the next highest Mn ÷ C ratio in this group and the crack initiated at the flame-cut handling hole did not propagate.

4 – It is probable that the higher copper in Sample E than Sample C, otherwise similar in composition, is beneficial.

5 – The 15 ft-lb. transition temperature of Sample E, which of course is affected by factors No. 2, 3 and 4, is 50° F. lower

Table III – High-Phosphorus Piling Which Failed in a Single Wharf

	J	K	L	M	N	O	P	Q
Composition								
Carbon	0.30	0.30	0.32	0.27	0.29	0.29	0.26	0.30
Manganese	0.70	0.55	0.64	0.60	0.60	0.65	0.53	0.55
Silicon	0.03	0.04	0.06	0.10	0.08	0.09	N.d.‡	N.d.‡
Sulphur	0.030	0.030	0.038	0.035	0.035	0.032	0.025	0.028
Phosphorus	0.111	0.063	0.078	0.079	0.091	0.064	0.056	0.073
Chromium	0.02	0.02	0.02	0.03	0.02	0.03	0.02	0.03
Nickel	0.04	0.05	0.05	0.05	0.04	0.05	0.05	0.05
Copper	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
Mn÷C ratio	2.3	1.8	2.0	2.2	2.1	2.3	2.0	1.8
Web thickness, in.	0.81	0.5	0.375	0.5	0.375	0.375	0.375	0.375
Tensile tests*								
Yield†	49,700	47,500	50,400	—	—	—	—	—
Ultimate	85,300	82,500	85,600	—	—	—	—	—
Elongation in 2 in.	29.0	22.0	22.0	—	—	—	—	—
Transition temperature								
At 15 ft-lb. energy	154	109	91	87	82	90	90	109
Average energy	149	122	88	127	109	133	149	160
At 50% shear	194	140	108	131	118	126	153	172
Energy absorbed								
At 32° F.	6	5	6	4	3	4	4	6
At 75° F.	7	11	12	11	12	15	12	8

*Subsize tensile tests †0.2% offset ‡None detected

than for any of the other steels in this group. However, this is above its temperature when it was driven, and it is concluded that the smooth edge of the handling hole is primarily responsible for its apparent toughness.

Plain Carbon Steels

Establishing a Datum – Table II and Fig. 5 present data on four pieces of plain carbon steel of superior quality, produced at our request by as many steel companies.

The results of tests on these steels are useful in indicating the relationship between their composition, tensile properties and impact values and those of other steels which failed, and this should provide a yardstick in setting up a satisfactory specification.

It will be apparent from comparison with data in other tables that these steels have low transition temperatures* and absorb a high amount of energy in impact tests at 32° F. Tramp elements, but especially phosphorus, in these steels are low. Phosphorus is 0.011 to 0.032% as compared with the next group in Table III (0.056 to 0.111) – a matter which we think is significant.

High-Phosphorus Steels – No failures of carbon steel piling have been reported during driving operations. However, cracks have been discovered during the life of the piling, with indications that they were initiated at flame-cut holes in the bottom of the

*Values for our sub-size Charpy bars are plotted in the figures, and experience indicates that these values represent 82.5% of the breaking strength of a standard-sized Charpy bar. Therefore, in order to get the 15 ft-lb. transition temperature we measure the temperature at which the 12½ ft-lb. line crosses the curve. Similarly the energy absorbed at 32 and 75° F. reported in the tables is increased proportionally from the values scaled from the graphs.

Table IV – Piles Which Failed by Fatigue

	R	S	T	U
Composition				
Carbon	0.35	0.39	0.38	0.34
Manganese	0.98	0.98	0.94	0.92
Silicon	0.15	0.15	0.14	0.14
Sulphur	0.028	0.025	0.028	0.023
Phosphorus	0.030	0.035	0.039	0.027
Copper	0.11	0.11	0.12	0.12
Mn÷C ratio	2.8	2.5	2.5	2.7
Web thickness, in.	0.5	0.5	0.5	0.5
Tensile tests†				
Yield‡	53,000	57,450	53,750	57,450
Ultimate	77,350	87,950	74,750	88,750
Elongation in 8 in.	17.0	13.5	13.0	12.5
Transition temperature				
At 15 ft-lb. energy	43	53	10	55
Average energy	72	68	43	111
At 50% shear	77	100	48	120
Energy absorbed				
At 32° F.	10	6	21	8
At 75° F.	35	24	63	24

†Flat test pieces, pitted surface. ‡By drop of beam.

pile. The majority of the failures were of Type II (Fig. 2) and these were especially evident in samples J and Q (Table III) after they had been in service for some time.

Following a heavy storm, cracks were noted in the wharf from which these samples were taken. Subsequent storms during the winter broke more of them until a total of approximately 85 piles were damaged. Several of the cracks were initiated at arc strikes, but the majority started at weld undercuts in the tie-rod bearing plates or from irregularly flame-cut holes. One crack followed a heavy blow from a ship.

Laboratory tests on the samples showed that every one of them, even in the thinner 0.375-in. webs, was notch-brittle. The lowest 15 ft-lb. transition temperature was 82° F., which is approximately 50° F. higher than the water in winter. The highest energy absorbed at 32° F. was 6 ft-lb., and the tensile strengths were in the range 82,500 to 85,600 psi. These results are unfavorable when compared with those from samples F to I in Table II, where the 15 ft-lb. transition temperatures were below 40° F. and the impact values at 32° F. well above 10 ft-lb. The tensile strengths of these tougher samples in Table II were also lower, being in the range of 66,000 to 78,750 psi.

As noted before, the phosphorus content in these steels was high, well above the normal values given in A.I.S.I. steel specifications, and the Mn ÷ C ratio on the low side (1.8 to 2.3). Representative Charpy versus temperature curves are given in Fig. 6. Samples J and K, which possessed high 15 ft-lb. transition temperature, have the lowest silicon contents and are rimming or semikilled bessemer steels. These bessemer steels, however, also possessed the highest phosphorus contents, and we believe that the phosphorus rather than the steelmaking method is the factor promoting notch brittleness.

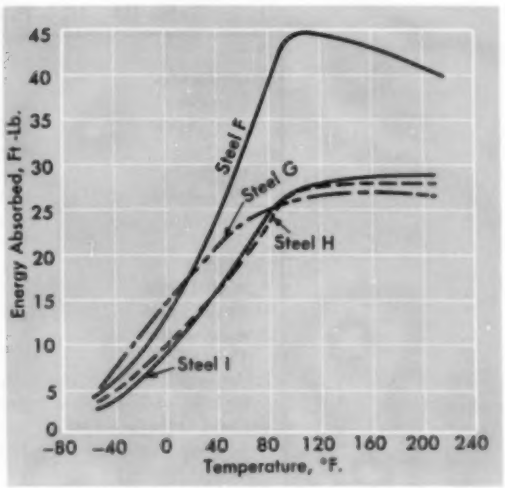
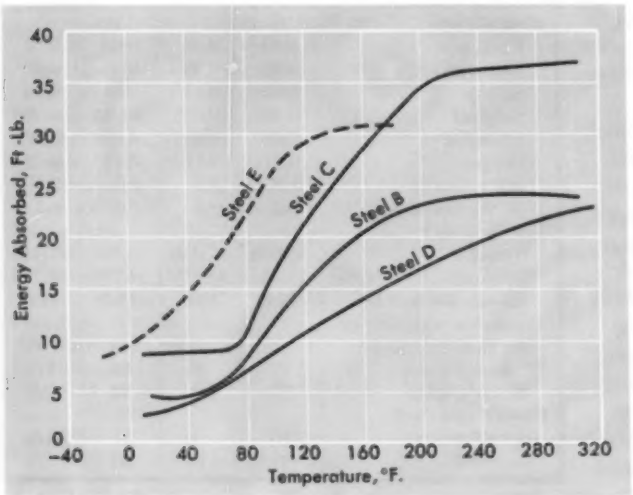


Fig. 5 — Impact Versus Temperature for Four Plain Carbon, Low-Phosphorus Steels of Superior Quality

Type III failures (brittle failures starting at fatigue cracks) occurred in piles from which steels R to U in Table IV and Fig. 7 were taken. In this group of four, there were in fact two types of failures, one due entirely to fatigue and the other due to brittle failure initiated by a fatigue crack. The fracture surface of sample S is shown in Fig. 3. The herringbone pattern typical of notch-brittle failure extends about two thirds of the way across the web, the other third being a fatigue crack which seems to have started at a corrosion pit in the recessed parts of the interlock. Samples S and U had this type of failure, while samples R and T showed a complete fatigue fracture across the web, starting at a corrosion pit in the interlock.

The structure from which these samples were removed was about 15 years old, and much of the original earth back-fill had washed

Fig. 4 — Energy Absorbed (Sub-Sized Charpy Tests) Versus Temperature for Four of the Alloy Steels



away; thus, during the winter storms the piles were free to vibrate under wind and wave. It is interesting, also, to note that failure was not initiated at any defect due to bad workmanship; corrosion pits and lack of back-fill seem to have been the main causes, but the damage to the wharf would probably not have been as catastrophic if the steel had been of sufficient notch ductility at the service temperature to prevent crack propagation.

The 15 ft-lb. transition temperatures of R and T are lower than for S and U; furthermore the impact values at 32° F. are higher. Steels R and T also have tensile strengths in the range of 74,750 to 77,350 psi. compared with 87,950 to 88,750 for S and U.

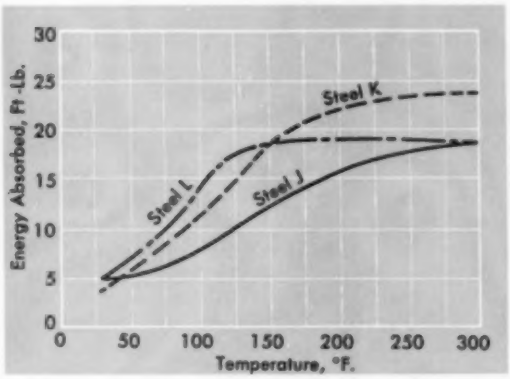


Fig. 6 – Impact Versus Temperatures for Three Steels, High in Phosphorus, Representative of 85 Broken Piles Removed From a Single Wharf

General Discussion – The service behavior of the steels indicates that low-temperature brittle fracture occurred in almost all samples possessing a 15 ft-lb. transition temperature higher than the service temperature. The only exceptions were samples E and R, where the transitions are only about 20° and 13°, respectively, higher than an estimated service temperature of 30° F. In sample E, an alloy steel, the superior behavior may be due to the fact that the web is much thinner than in the other alloy steels examined.

A marked feature of all the samples in any group is that the transition temperature increased with increasing tensile strength. Phosphorus, too, was very effective in increasing the notch brittleness (lowering the transition temperature).

The design and construction of the assembly must be considered carefully, because all failures could be traced to the following defects:

1. Irregularly flame-cut holes, serving as a mechanical and metallurgical notch. This could be minimized by using a template for the cutting torch.

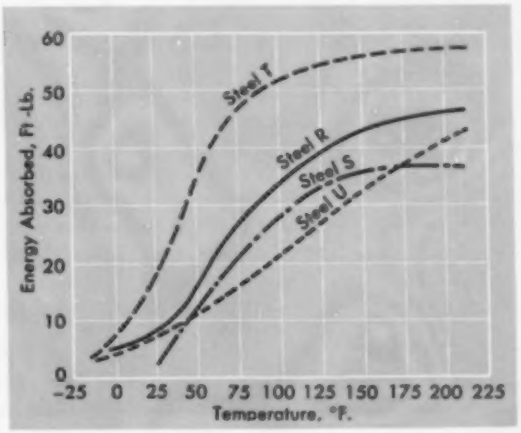
2. Poor welding techniques, such as undercutting, arc strikes, and absence of preheating or postheating.

3. Corrosion pits. Some of these might have been caused by original surface defects in the piling. The only way to provide against such irregularities is to use steel of adequate notch ductility to prevent crack propagation from these pits when they grow to a critical size after several years of service.

The above considerations lead to the suggestion that sheet piling specifications should call for lower carbon and higher manganese contents. (Alloy steel piling requires careful design and construction; the importance of stress concentrations cannot be over-emphasized).

Generally the steel rolled into steel sheet piling has been of the lower grades of structural steel, and it has been contended that it is a needless expense to specify a better quality steel in view of the past favorable service. While our investigations cover only a very small percentage of the total tonnage built into piling structures, no one knows how close to failure standing piling structures are. At the same time, the failure of piling initiated at corrosion pits indicates that years of service may elapse before these pits do become crack starters in steel of low notch sensitivity. However, when this happens in steels of the grades now commonly specified, they can cause catastrophic failure of the structure at low temperatures.

Fig. 7 – Impact-Temperature Curves for Four 15-Yr. Old Piles Which Failed in Fatigue



Troubles With Atomic Submarine "Seawolf"*

[The Department of Defense issued the following statement Nov. 16, 1956:]

"Leaks in the steam superheating system of the 'Seawolf' propulsion plant have delayed the dockside testing of the ship. Technical studies have been under way to determine the exact source and extent of the difficulty. As a result corrective action is being expedited.

"No difficulty has been experienced with the nuclear reactor itself, but only with its cooling system, and the safety of the plant has not been impaired.

"The 'Seawolf' reactor is cooled by liquid sodium; it is the only plant of this type installed or planned for installation in a naval vessel. The 'Nautilus' type of plant, which uses pressurized water as the coolant, is used in all other nuclear ships which are being built for the Navy. The two designs were undertaken simultaneously because the need to develop a nuclear-powered submarine was great and it was not known then which would be the more successful for submarine propulsion."

[This report caused much speculation unsupported by known facts, as all details of military reactors are classified as "Secret". Mr. Davis's talk is the first authoritative information that has become available:]

The "Seawolf" reactor is cooled with molten sodium which comes out of the reactor at a high temperature and with a high level of induced radioactivity. The problem is to transfer this heat to water to produce steam to drive the propulsion turbines.

Experience has indicated that violent [explosive?] reactions between sodium and water are producible under carefully controlled experimental conditions. Accidental mixing has produced only moderate reactions. Nevertheless, it is undesirable to contemplate exchange of heat directly [in a simple tubular-type heat exchanger?] between radioactive sodium and water until considerably more experience has been gained.

In a central station power plant where space and weight are not of such importance as they are in a submarine, one can use an intermediate heat exchange loop with completely separate heat exchangers, wherein the radioactive sodium exchanges heat with nonradioactive sodium (or a Na-K mixture having a much lower melting point), which in turn generates and superheats the steam in a second heat exchanger. This does not eliminate all possibility of a reaction between liquid metal and water but it does limit such reactions to nonradioactive substances.

However, this is not feasible in a submarine, and the "Seawolf" uses a double tube heat exchanger wherein the radioactive sodium from the reactor is pumped through the inner tube, nonradioactive sodium-potassium (Na-K) is maintained (not flowing) in the annular space between the central tube and the outer tube, and steam is generated or superheated by contact with the outside of the double tube. The [double-walled or compound] tubes are bent into a "U" to provide freedom for linear expansion and welded into tube sheets. Pressures are maintained so that any flow from a leak would be from the water side to the nonradioactive Na-K, and from the nonradioactive Na-K into the radioactive sodium.

Such heat exchangers are subject to stresses from fabrication, from the pressures and expansions caused by the operating temperature, and from transient temperature changes which may be large and rapid. Corrosion may occur in the sodium side if impurities, particularly oxygen, cannot be maintained at extremely low levels. The water side is subject to corrosion from water as well as from impurities, such as chloride ions, which are particularly difficult to keep out in a naval plant. Both sides are also subject to corrosion if there is any leakage and reaction between sodium and water. The choice of suitable materials and fabrication methods is obviously difficult.

Steam generators and superheaters for the "Seawolf" were tested for extended periods of time and what appeared to be satisfactory designs were arrived at. However, the experience with the land-based prototype at West Milton, N. Y., and with the "Seawolf" has shown that leaks do develop, particularly in the superheaters. The exact cause of this failure has not yet been determined. Both plants are now operating with the leaking superheaters bypassed, and it is expected that the "Seawolf" will operate at approximately 80% of its designed power.

Does this experience with the "Seawolf" mean that sodium-cooled reactors are unsuitable or unsafe for central station power plants? The answer is an emphatic "No!"

(*Continued on p.* 116)

*Portions of an address by W. Kenneth Davis, Director of Reactor Development, U.S. Atomic Energy Commission, before Southwide Chemical Conference, Dec. 7, 1956. Words in brackets [ ] are by The Editor.

Electric Furnace Steel Conference

*Reported by E. C. WRIGHT**

Economics of the electric steel industry loomed large in the discussion, what with the excessively high cost of steel scrap. Other raw materials for the non-integrated producer which were considered are sponge iron, hydrogen reduced iron, and desiliconized pig iron from cupolas. (D5, D9; ST, Fe RM)

THE 13th annual Electric Furnace Steel Conference was held by the American Institute of Mining, Metallurgical and Petroleum Engineers in Chicago in December last and was attended by over 1000 registered participants and many other guests. Incidentally, the date marked the 50th anniversary of the installation of the first electric arc furnace in America. This first furnace was designed by Paul Heroult, inventor of the arc melting furnace, manufactured by Société Electro-Metallurgique Francaise, and shipped to Syracuse for assembly at the toolsteel plant of Halcomb Steel Co. (now a unit of Crucible Steel Co. of America). Howard Stagg has written an engaging story of this event and its aftermath in *Metal Progress* for April 1956.

The first day of the three-day meeting was devoted to visits to electric steel plants near Chicago. In the next two days six technical sessions were held comprising some 27 papers.

The first session was general in nature. Robert Bourigny, director of engineering of Stein & Roubaix of Paris, gave a thorough summary of the electric steel melting plants of Europe, exclusive of England. He emphasized the important economic applications of the arc furnace, especially in Italy and the Scandinavian countries which lack mineral fuels yet possess considerable water power resources. Since Europe will probably have to import more and more of its fuel at greater costs, Mr. Roubaix anticipates that many more electric furnaces will be installed. European furnaces are usually much smaller in capacity (15 to 50 tons) than most recent American ones. Operating features are quite similar to American melting practices when melting cold scrap. A notable exception was cited from the Ruhr district in Germany which uses molten hot metal in the charge, and blows oxygen into the furnace to oxidize metalloids

*Consulting Editor, *Metal Progress*, and Head of the Department of Metallurgical Engineering, University of Alabama.

in the pig iron, thus increasing production per hour with less electric power per ton.

In this same session Sam Arnold (American Bridge Div., U.S. Steel Corp.), one of the real veterans of the industry, gave a historical résumé of 50 years of electric furnace melting. (Much of this information has already appeared in Howard Stagg's paper in *Metal Progress.*) In speculating about the probability that even larger arc furnaces will be built than the 200-ton furnace at McLouth Steel Corp. in Detroit, he said it would probably be necessary to go to a six-electrode furnace, equipped with two transformers and two feeder circuits. He believes that electrode sizes and transformer engineering might be too difficult in a three-electrode furnace of greater capacity than 200 tons. He pointed out that one 100-ton, six-electrode furnace had already operated successfully for 25 years at Timken Steel & Tube in Canton, Ohio.

Robert Bry, of the transformer division of General Electric Co., then presented an interesting study of the growth of the electric furnace industry, with especial references to the future requirements for transformers. He advanced the thesis that most new products undergo three distinct periods of growth: First is a developmental stage; there is a small output for a year or so. Second, a successful innovation then surges forward for about five years of very rapid growth. Following this is a third and slower "normal" growth lasting about 20 years. Electric furnace output shows a curve of growth conforming to type; it remained below 1% of the total steel tonnage until 1945, then increased rapidly to 3.75% in 1950, and has since grown yearly at a slower rate. His figures indicate that 25% of all alloy ingots in the United States are now made in electric furnaces and he estimated that about 15% of all carbon steel might be made in electric furnaces by 1975. This would amount to 25 million tons of carbon steel ingots, and would require an annual increase of about 1,000,000 tons of electric furnace capacity for the next 20 years. From these figures, and based on a figure of 5 tons of steel per kva. available, Mr. Bry estimated that at least 200,000 kva. of transformer equipment will be needed each year for carbon steel ingots, exclusive of expected increases annually in alloy steel ingots.

Charge Materials

A timely paper entitled "Cyclical Movement of Steel Scrap Prices" was presented by Chapin Hoskins of the Institute of Trend Research, of Hopkinton, N.H. This study covered the years from 1900 to 1956 and showed great variations in prices in both long and short cycles. What caused these cycles was not brought out and no future trend based on these statistics could be safely predicted.

The present reporter would comment on the fact that the cost of steel scrap is probably the most serious problem facing all cold-melt electric furnace plants today. Much discussion of this problem occurred in the corridors. With many integrated hot metal plants producing ingots for about $55.00 per net ton, how can a cold melt electric furnace plant produce steel from 95% cold scrap charge when the scrap alone costs $54.00 per net ton, and melting and operating costs amount to $20.00 per net ton even in a sizable plant of 300,000 tons annual output?

This difficult scrap price situation has caused many electric furnace operators to look for substitutes for steel scrap and four papers considered this subject. One by P. E. Cavanagh of the Ontario Research Foundation, Toronto, presented the Canadian viewpoint. He discussed briefly the technical and economic aspects of using molten pig iron, high-grade iron ores (65% Fe), sponge iron (over 80% Fe), blown metal or desiliconized hot metal, and hydrogen reduced iron (H-iron). He is highly doubtful about the economies of using normal hot metal in large quantities in electric furnaces if the metalloids must be oxidized with iron ore, because of the large ore charge required, large slag volume and excessive foaming from gas generated by the 4% of carbon in the molten pig iron. Direct reduction of high-grade iron ore in the Tysland-Hole arc furnace is not attractive because of very high power consumption, large slag volume, and low output.

Sponge iron with over 85% iron does not seem to be an economical raw material in America, as it costs $45 to $55 per ton to produce. It also presents many operating difficulties, such as poor conductivity, high melting temperature, slow melting, considerable slag volume from the gangue in the sponge iron, and low bulk density. Storage of sponge iron in sealed containers to prevent oxidation is also a great nuisance. However, the present availability of pelletized iron ore concentrates, and an increased quantity of high-grade imported ores (over 60% iron), keeps interest in sponge iron very much alive.

At this same session John Stalhed, manager

of the sponge iron plant operated by Stora Kopparberg at Falun, Sweden, gave an interesting review of the use of sponge iron in electric furnaces in his country. Under the special economic conditions existing there, sponge iron can be charged in electric furnaces in amount up to 70% of the total iron charged. Only the purest grades of iron ore are used for the manufacture of sponge (at least 65% Fe). Either lump ore or 1-in. pellets are used in the Wiberg-Soderfors shaft furnaces* and the cost of the sponge iron, about $32 per metric ton, is much below the cost of imported scrap. About 100,000 tons a year of this sponge iron is used in small electric furnaces of 10 to 15-ton capacity in Sweden for making very special toolsteels, ball bearing steels, spring steels and wire and other products of high quality.

Mr. Stalhed gave the following analysis of the sponge iron: metallic iron 82%, total iron 91%, proportion of iron reduced 91%, carbon 0.9%, phosphorus 0.010%, sulphur 0.010% and non-metallic gangue 6.50%. This high-purity material is particularly desirable for special steels because it is free from tramp alloys. However, the hot sponge iron must be cooled in a reducing atmosphere and then sealed in airtight containers of 4 to 5 tons capacity until ready for charging.

In making steel with 50% sponge, a mixture of scrap steel and pig iron is first charged and melted; a can of 3.6 tons of sponge iron is then charged and melted down; one hour later another 3.6 tons of sponge iron is added. In this 13-ton furnace enough pig iron is used to get a final meltdown of about 0.70% carbon. Total heat time is 6¾ hr.; power consumption is 813 kw-hr. per metric ton, and melting rate is 2 metric tons of steel per hr. Since the phosphorus in the charge is very low the lime-silica ratio in the slag is only 1 to 1.

H-Iron – In his paper presented earlier in this same session, Mr. Cavanagh also touched briefly on the use of H-iron in electric furnaces. This method of producing sponge iron by means of a "fluidizing" technique and a reducing roast at 900° F. with hydrogen or coke oven gas at high pressure, has been technically successful, but the economics of the whole process are still quite vague.* The operation requires a very pure grade of iron ore and a cheap source of reducing gas. Cavanagh estimated H-iron at $45 to $55 per ton if natural gas costs less than 50¢ per 1000 cu.ft. (One might also question whether the hydrogen content of this material would not be too high to be safely used in steel going into heavy sections such as large forgings, die blocks, and special toolsteels.) Those interested in the economics of direct iron, reduced by hydrogen, should turn to the friendly debate between P. E. Cavanagh and Harry W. McQuaid as the question, "Is the Reduction of Iron Ore by Hydrogen a Commercial Possibility?" printed in *Metal Progress* for April 1951, p. 523.

Hot Metal – S. L. Case, technical advisor at Battelle Memorial Institute, Columbus, Ohio, briefly discussed the use of normal hot metal (4% carbon, 1.2% Si) and desiliconized hot metal

*Described (with cost analysis) in *Metal Progress* May 1950, p. 633.

*Fluo-solids roasting may be described as a gas-solid reaction wherein the reacting gas is blown up through a bed of finely divided mineral at a regulated pressure which keeps the mineral suspended in the gas stream. Pressure, temperature and particle size must be adjusted for any given reaction.

Hungarian Relief

The Editor is authoritatively informed that American relief agencies are now unable to guarantee that packages can be delivered to individuals within Hungary, and even shipments to orphanages or hospitals cannot be made with any regularity.

However, the refugees newly arrived in Austria have many pressing needs. More than half of them are children and young people under 21. They lack such important essentials as baby foods, dry clothing, blankets and personal necessities.

In this emergency about all that individual Americans can do is to send cash to some agency which is actively operating along the Austrian-Hungarian border, such as the American Friends Service Committee, 20 South 12th St., Philadelphia, Pa., or CARE, 550 First Ave., New York 16, endorsing their checks "For Hungarian Emergency Relief".

in electric furnace charges. He emphasized the difficulties resulting from the very heavy charges of ore (and the resultant high slag volume) needed to refine the melt of its impurities. In the opinion of the present reporter he might well have pointed out that the sensible heat gained in the molten hot metal is just about balanced by the heat required to reduce the iron ore, so there is no net thermal gain. He further neglected to mention that a very active boil, generating over 1000 cu.ft. of CO gas per ton (or 33,000 cu.ft. per hr.) results if 50% hot metal is charged in an electric furnace. It would be necessary to put a hood and stack over such a furnace; the dust control problem would be greatly aggravated.

Based on such considerations as he advanced, Mr. Case stated that desiliconized hot metal will probably be a necessity in the near future in integrated steel plants. In this author's opinion it has at least seven advantages over ordinary hot metal for either openhearth or electric furnace. Unfortunately many important electric steel producers do not operate fully integrated plants and have no molten hot metal available. The non-integrated electric furnace plants are obviously going to have to live with the price of steel scrap, or turn to new methods of making hot metal other than building a costly blast furnace and coke oven plant.

Steel Castings

The steel casting producers listened to a striking paper by C. F. Christopher, director of research for Continental Foundry & Machine Division, Blaw-Knox Co., East Chicago, Ind. It concerned the relationship of deoxidation of melts and steel solidification to hot tearing defects. Most of his data were derived from impact tests made on hot test pieces and broken in an argon atmosphere. A curve summarizing the results showed low values at 1100° F. (under 20 ft-lb.) rising sharply to 180 ft-lb. at 1300° F. and then falling steadily to a very low figure between 2400 to 2600° F. The temperature for the minimum value depended on the type of steel tested. All the steels remained tough throughout the austenitic range until the solidus temperature was reached, and then all became very weak and brittle.

Mr. Christopher pointed out that in steel castings, improper feeding of molten metal to a solidifying mass will allow hot tears to develop from the shrinkage strains existing in the section when it reaches the solidus temperature. Samples heated and cooled in argon to temperatures between the solidus and liquidus showed grain boundary eutectics which greatly weakened the metal. High-carbon heats, silicon killed heats from acid furnaces, the presence of iron sulphide and iron oxide, all increased the amount of such grain boundary eutectics. Basic steel heats, killed with aluminum, showed hot tear temperatures about 100° F. higher than acid heats, other factors being the same.

L. H. Nelson, director of conservation and yield control for Crucible Steel Co. of America, Pittsburgh, described an interesting study of shrinkage and density of hot topped, killed steel ingots of various shapes and corrugations. Shrinkages were calculated from the inside dimensions of the mold and the outside dimensions of the cold ingots, and all ingots were weighed to determine the density. He found:

1. Shrinkage in the outer shell during solidification and cooling is about 9.1%.
2. Total shrinkage, including pipe cavity, is about 11.1%.
3. The density of liquid steel as poured is about 0.2511 lb. per cu.in.
4. There is unequal shrinkage across an ingot section and this varies considerably with the contour of the mold cavity.

A great deal of work has been done in recent years at the U.S. Naval Research Laboratory in Anacosta, Md., and Wm. S. Pellini, superintendent of the metallurgy division, summarized about two dozen of the researches on solidification of various metals in ingot and sand molds. The relation of the mode of solidification and the shape of the phase areas in equilibrium diagrams is clearly brought out. Thus, a solid solution alloy like brass, with wide temperature range between the liquidus and solidus, freezes with a slightly progressive wall growth; then develops a mushy condition throughout the casting volume; and finally solidifies completely with a tardy growth of a completely solid skin. Cast steel shows highly progressive wall growth — that is by narrow freezing regions and early growth of completely solid skin. The hypo-eutectic gray iron (and also nodular iron) goes through a two-stage solidification — the initial development of mushy solid solution and final solidification by highly progressive eutectic formation. These cast irons are unusual in that they expand during the liquid-to-solid transition rather than shrink, as do most metals.

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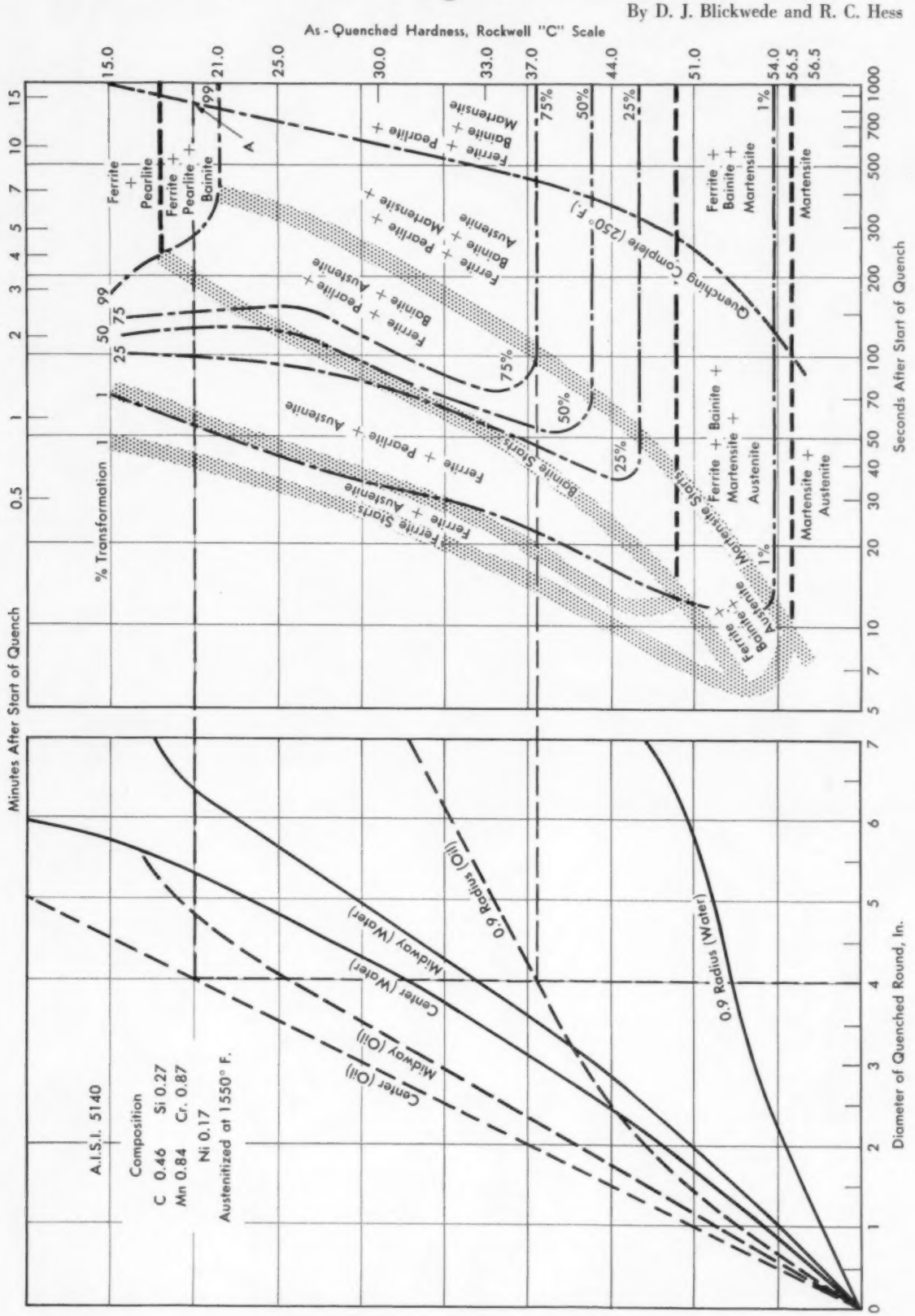
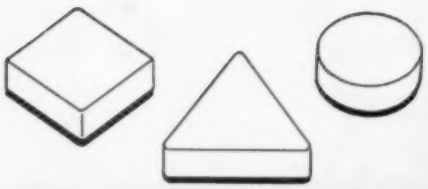
Heat Treatment Diagram for A.I.S.I. 5140

By D. J. Blickwede and R. C. Hess





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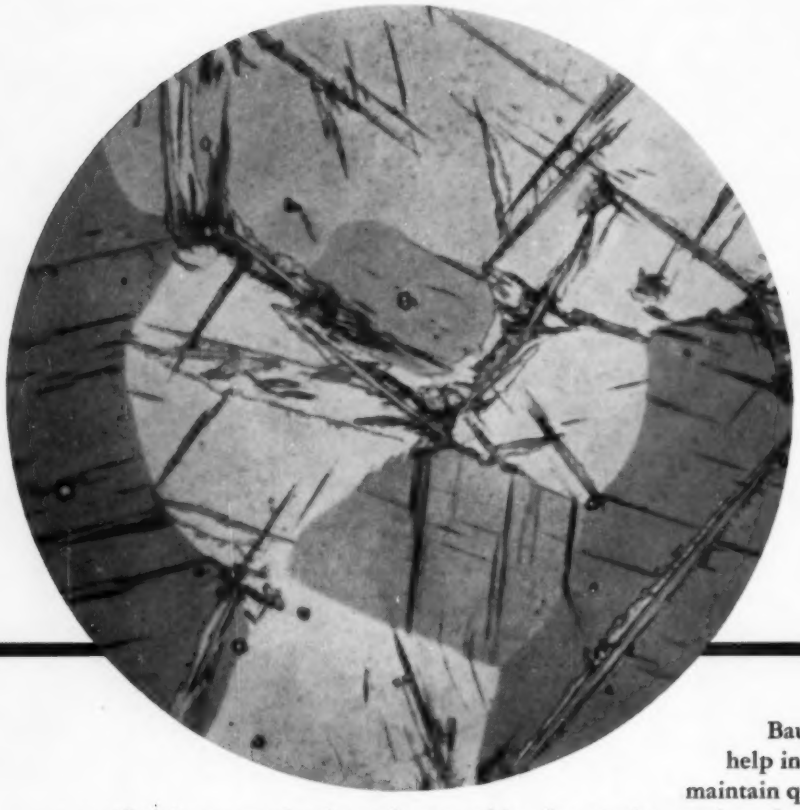

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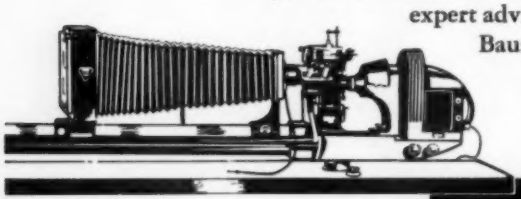

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Slack Quenching of Steels

*By D. J. BLICKWEDE and R. C. HESS**

Quenching diagrams are presented for several common engineering alloy steels which enable the metallurgist to predict the course of transformation and the eventual microstructures and hardnesses of various sized parts quenched either in oil or water. (J26n, N8p; ST)

A FREQUENT PROBLEM for metallurgists who deal with the specification and heat treatment of steel is to predict the way different steels will respond to quenching. The objective, of course, is to choose the right grade of steel and the right treatment for the job. Ideally, this boils down to a matter of choosing a steel which will transform to the desired structure *throughout* the quenched part.

A fully martensitic quenched structure is generally preferred because, after proper tempering, it has the best combination of toughness, ductility and strength. However, more often than not martensite cannot be obtained in the slowly cooled central sections of a part except by the use of expensive alloy steels. This economic limitation forces metallurgists to accept and learn to deal with slack quenched steels having non-martensitic or partially martensitic structures containing ferrite, pearlite and bainite. ("Slack quenching" may be defined as incomplete quenching. Slack quenching occurs in commercial practice if the rate of cooling is too slow, or the section too large in relation to the mass or hardenability of the steel to result in a completely martensitic microstructure.)

Obviously it would be helpful in the selection and specification of the many steels on the market to know in advance the relative amounts of these constituents which may be expected in slack quenched parts. To serve this need, relatively simple charts have been devised from which one can make such predictions, as will now be described, together with examples of how they are used.

It might be helpful, first, to review very briefly some of the general effects of structure on the properties of steel. Unfortunately, there is not too much accurate information on this subject, but experience permits some generalizations:

It has already been mentioned that a fully martensitic structure is generally desired in as-quenched steel, since it has the optimum mechanical properties after tempering. In the charts to be described, the other as-quenched structural constituents are ferrite, pearlite, bainite and retained austenite. (No distinction has been made between coarse pearlite and fine pearlite, or high bainite and low bainite, but for the steels and cooling rates covered here, the

*Dr. Blickwede heads the physical metallurgy division of the research dept. of Bethlehem Steel Co., Bethlehem, Pa., and Mr. Hess is research engineer in the same department. Further information on the general topic was presented by the same authors to the ASM convention last October, in Preprint No. 17, "On the Cooling Transformations in Some 0.40% C Constructional Alloy Steels", (digested in *Metal Progress*, Sept. 1956, p. 172). See also J. L. Lamont's article, "How to Estimate Hardening Depth in Bars", printed in *Iron Age*, Oct. 14, 1944, p. 64.

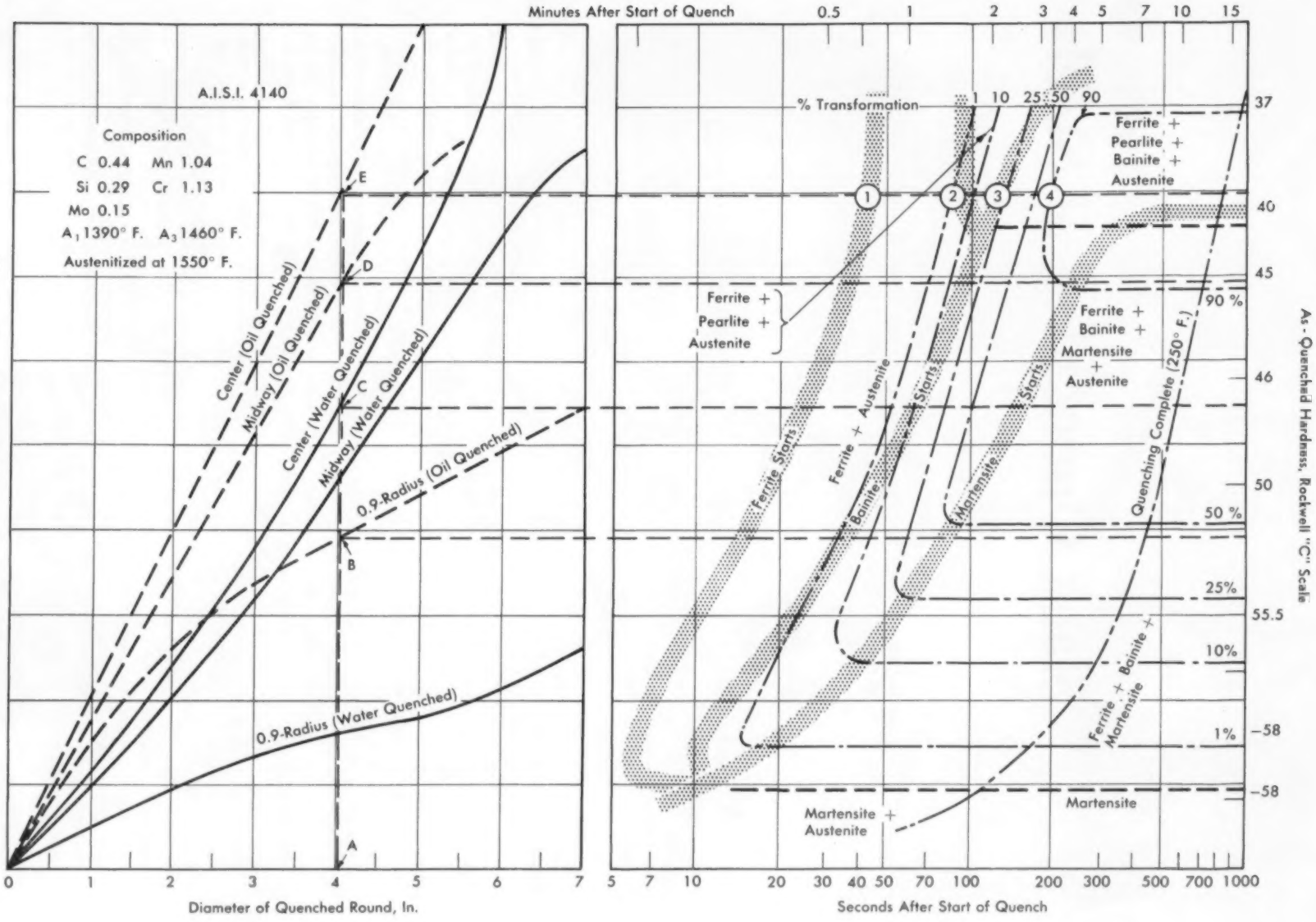

Fig. 1 — Heat Treatment Diagram for A.I.S.I. 4140

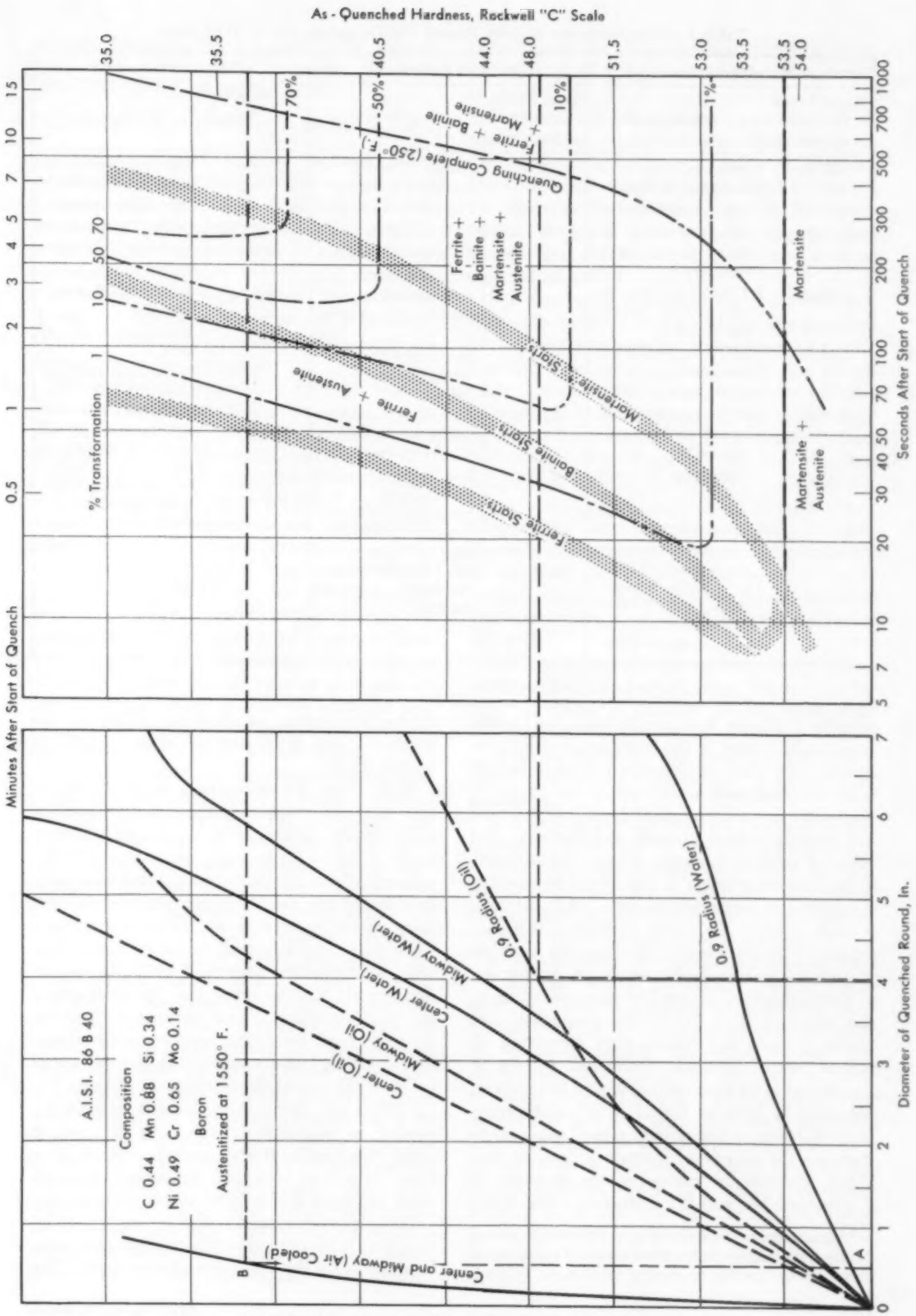

Fig. 2 – Heat Treatment Diagram for A.I.S.I. 86 B 40

Table I – Transformation of 4-In. Round, Oil Quenched Bar of 4140 Steel

Center of Bar		Midway Location		0.9-Radius Location	
Time After Start of Quench	Structure	Time After Start of Quench	Structure	Time After Start of Quench	Structure
40 sec.	Austenite starts to transform to ferrite	35 sec.	Austenite starts to transform to ferrite	15 sec.	Austenite starts to transform to ferrite
80 sec.	1% ferrite formed	70 sec.	1% ferrite formed	35 sec.	1% ferrite formed; bainite starts to form
90 to 100 sec.	Pearlite starts to form, concurrently with ferrite	85 sec.	10% ferrite formed	45 sec.	Austenite 10% transformed
		95 sec.	Bainite starts to form	60 sec.	Austenite 25% transformed
120 sec.	25% ferrite + pearlite has formed; bainite starts to form	120 sec.	40% of austenite has transformed, approximately 30% to bainite	90 sec.	Martensite starts to form
170 sec.	50% of austenite has transformed, about half of it to bainite	210 sec.	Austenite 90% transformed, mostly to bainite	7 min.	Quenching virtually complete. As-quenched structure consists of approximately 40% bainite, 1% ferrite, remainder martensite. Hardness approximately C-52
200 sec.	90% of austenite has transformed, mostly to bainite	220 sec.	Remaining austenite starts to transform to martensite		
15 min.	Quenching virtually complete. (Temperature at this location below 250° F.) As-quenched structure consists of 90% bainite + ferrite + pearlite and 10% retained austenite. Hardness approximately C-39	10 min.	Quenching virtually complete. As-quenched structure consists of 90% bainite + ferrite, no pearlite, 10% martensite. Hardness approximately C-45		

pearlite is always fine lamellar and the bainite is generally formed in the lower range of temperatures.) Of these constituents, tempered bainite is the one that most nearly approaches tempered martensite in tensile properties, while both ferrite and pearlite reduce strength and ductility. The effect of retained austenite is more complicated, depending on whether it transforms or whether it conditions* during tempering. If it transforms, it tends to lower the tensile properties; if it conditions, it raises strength but impairs ductility (unless the steel is double tempered, of course).

Notch ductility of steel is more sensitive to the structure than the tensile properties, and ferrite, pearlite and bainite after tempering all reduce notch ductility. Tempered bainite is considered to be least detrimental in this respect, but even as little as 10% of it in an otherwise tempered martensitic structure has been said to decrease the energy to fracture a notched bar. When austenite is retained in the structure of a quenched bar and it transforms or conditions during tempering, its damaging effect on the notch ductility of the part would be expected to be still worse.

With these generalizations in mind, let us now turn our attention to the charts or quenching diagrams shown in Fig. 1 and 2 and the data sheet, p. 96-B. From these we can predict the amounts of the microconstituents that will occur in different size rounds in three commonly used alloy steels, quenched in different mediums. They may also be used to estimate the time after the start of the quench at which the various constituents start to form, and the hardness of the final structure. These quenching diagrams were derived from the experimentally determined cooling transformation diagrams presented by us to the recent ASM convention (Preprint No. 17, 1956) and the data of Lamont relating the cooling in quenched rounds with the cooling along the length of end quench hardenability bars. It will be seen that predictions based on them correspond closely to actual observations.

Probably the simplest way to explain these diagrams is by examples of heat treatment problems involving the evaluation of structures. The

*"Conditioning" is defined as a process occurring during tempering which causes retained austenite to transform to martensite during subsequent cooling.

following examples are not necessarily typical; some are hypothetical in order to illustrate clearly certain transformation features.

Case I – Structure Distribution in Large Bar

A cylindrical part, 4 in. in diameter at its largest section, must be quenched so that it has a minimum hardness of C-50 at 0.25 in. below the surface (approximately 0.9-radius position in the bar). A.I.S.I. 4140 seems to have sufficient hardenability so an oil quench will meet this requirement. But what about the structure throughout the part? Is it reasonably uniform? Does it contain any constituents that may be detrimental to the properties?

The quenching diagram for a typical heat of 4140, the steel in question, is shown in Fig. 1. The curves on the left-hand portion of the diagram correlate the center, midway and 0.9-radius position in oil quenched (dotted lines) and water quenched bars (full lines) up to 7-in. diameter with the transformation characteristics shown on the right-hand portion. The latter shows the time after the start of the quench (the abscissa) at which the transformation products begin to appear, and their amounts existing throughout bars at any moment after quenching (the dash-dot lines). One diagram at the left suffices for all sizes of 4140 and all quenches, since the curves in the left-hand portion have been properly adjusted to the straight-line representing *"Center (Oil Quenched)"*.

Now, if we wish to see what the transformation characteristics of the center of an oil quenched 4-in. diameter round will be, a vertical line *A-B-C-D-E* is drawn on the left-hand section of the diagram at the 4-in. abscissa. At its intersection *E* with the curve marked, *"Center (Oil Quenched)"*, a horizontal is drawn across the right-hand portion of the diagram. Reading horizontally to the first shaded zone (Point 1), it may be seen that the center of the 4-in. round will start to transform first to ferrite about 40 sec. after the start of the quench, but reading further to the right to the first broken line (Point 2), after 80 sec. only 1% ferrite has formed. A few seconds later pearlite begins to form concurrently, and just before bainite starts to form (Point 3 at 120 sec.), the austenite is 25% transformed to a mixture of ferrite and pearlite. Further cooling forms more bainite until after 200 sec. (Point 4) the steel is 90% transformed. Continued cooling causes no further transformation so the as-quenched structure at this center position of the bar will contain about 10% retained austenite. The hardness of this mixture of ferrite, pearlite, bainite and retained austenite is about C-39.

Similarly, the progress of transformation at the midradius and 0.9-radius positions in the oil quenched 4-in. round may be followed by drawing horizontals across the right-hand section of the diagram from points *D* and *B*, the intersection of the 4-in. abscissa with the appropriate curve. The information thus obtained is summarized in Table I.

It is interesting to note in Fig. 1 and Table I that while both the center and midway positions of the 4-in. round are 90% transformed to a mixture of ferrite, pearlite and bainite, the center position is about 6 points softer than the midway position (C-39 versus C-45). Part of this may be due to the coarseness of the structure formed in the slowly cooled center. But it is also due to the large amount of retained austenite in the center position (10%) while the midway position contains 10% martensite. This tendency to retain austenite in slowly cooled sections is a peculiarity of this steel. As explained in our [redacted] paper, it is due to the carbon enrichment of untransformed austenite which takes place during the formation of ferrite.

It has been our experience that slowly cooled sections of 4140 steel will often become harder after tempering at 1100° F. This suggests that the retained austenite in these sections is conditioned by the tempering treatment and transforms to martensite when the part is cooling after tempering.

It is also of interest that the hardness of the as-quenched structure at the 0.9-radius position is C-52 – surprisingly high, in view of the fact that it is almost 50% transformed. Evidently this is because almost all the transformation occurred at low temperatures to bainite.

Reviewing the above information derived from the diagram, Fig. 1, for A.I.S.I. 4140, it would seem that from the surface to midradius (and probably deeper) of an oil quenched 4-in. round, the structure consists mainly of bainite and martensite. This might be expected to have moderate to good ductility and strength after tempering, and also moderate notch ductility. But it can hardly be said that the mixed structure at the center of the round, which contains retained austenite, would have good engineering properties. If the structure at this position is important to the service of the part, it might be preferable to water quench rather than oil quench.

Case II – Structure at Center

It is desired to avoid retained austenite in the center of a quenched 4-in. round of A.I.S.I. 4140. Will water quenching do this?

As before, the proper ordinate for using the right-hand portion of the diagram in Fig. 1 is obtained from the intersection of the 4-in. abscissa with the curve marked *"Center (Water Quenched)"* – namely, Point *C*. A line drawn horizontally from this intersection shows that transformation of austenite will progress as summarized below.

Time After Start of Quench	Structure
25 sec.	Ferrite starts to form
50	1% ferrite formed
60	Bainite starts to form
100	Austenite approximately 50% transformed, mostly to bainite
150	Martensite starts to form
600 (10 min.)	Quenching virtually complete. As-quenched structure will consist of 65% bainite and ferrite, mostly the latter; remainder martensite. Hardness about C-47.

From this it is evident that water quenching the 4-in. round will prevent retention of austenite in the center.

Before proceeding with further examples, we may digress a moment to say something about the accuracy of the predictions. This was established by quenching various sized rounds machined from a 4-in. bar from the same heat of 4140 steel on which the diagram of Fig. 1 was determined. The rounds were quenched either in agitated oil or water and tested for hardness and microstructure throughout their cross section. The test results are compared with the predictions from the diagram in Table II. It may be seen that the correspondence between predicted and actual hardness and microstructure is reassuringly good.

Case III – Desired Hardness at 0.9 Radius

Suppose the design of the part mentioned in Case I and II is such that the parts crack during a water quench. On the other hand, oil quenching of 4140 retains austenite. Can A.I.S.I. 5140, which has only slightly less hardenability than 4140, attain the desired hardness (C-50) at the 0.9-radius position?

The quenching diagram for a typical heat of A.I.S.I. 5140 is shown in the data sheet, p. 96-B. Again, a vertical line is drawn on the left-hand portion of the diagram from the 4-in. diameter point to intersect the curve marked *"0.9 Radius (Oil Quenched)"*. Reading from left to right from this point, it will be found that austenite transformation at this position in the bar will follow the sequence shown below:

Time After Start of Quench	Structure
15 sec.	Ferrite starts to form
20	Pearlite starts to form
25	1% ferrite + pearlite has formed
40	Bainite starts to form
60	50% bainite + ferrite + pearlite has formed
100	75% bainite + ferrite + pearlite has formed; martensite starts to form
7 min.	Quenching complete at this position (but not in the center, of course, which takes about 800 sec. or 13.3 min., as shown at Point A). As-quenched structure at the 0.9-radius position consists of 75% of a mixture mostly of bainite but with some pearlite and ferrite, plus 25% martensite. Hardness C-37.

It does not appear possible to use A.I.S.I. 5140 for this application because the hardness at the 0.9-radius position does not meet the specified minimum of C-50.

Case IV – Choice of Economical Steel

There are in stock bars of A.I.S.I. 4340, 9840 and 86 B 40 from which the part discussed previously could be made. Which of these grades may be oil quenched to meet the C-50 hardness specification at the 0.9-radius position? Which will give a reasonably uniform structure throughout a 4-in. round without using excessive alloy?

A quenching diagram for 86 B 40 is shown in Fig. 2*.

*Similar diagrams for 4028, 43 BV 14, 4340, 8620, 8640, 9260, 9310, 9840 and 52100 will be presented as data sheets in subsequent issues of *Metal Progress*. From them the range of structures that may be expected between the 0.9-radius position and center in each steel can be read, and it will be found that the 4340 and 9840 grades would harden to C-57 and so meet the hardness requirement, but the 86 B 40 at C-48 would not. At the same time the 4340 would give the most uniform microstructure throughout the part, being martensite with a little bainite. However, the lesser alloyed 9840 ought to serve quite well since it will only be about 15% transformed to bainite in the center of the 4-in. round and the hardness there would be about C-55. As shown in Fig. 2, the final structure in the fully oil quenched 86 B 40 part would contain all three of the microconstituents martensite, bainite and ferrite.

Table II – Comparison of Observed with Predicted Properties

Diameter	Quench	Position	Hardness		Microstructure*	
			Measured	Predicted	Observed	Predicted
1.0	Oil	Center	58.5	57	1% F + B	1% F, 4% B
1.0	Oil	Midway	57.5	57+	1% F + B	1% F, 2% B
1.81	Oil	Center	56	53	1% F, 15% B	1% F, 35% B
1.81	Oil	Midway	57.5	55	1% F, 10% B	1% F, 20% B
1.81	Oil	0.9 radius	57	57	1% F, 5% B	1% F, 8% B
1.81	Water	Center	59.5	57	1% F, 2% B	1% F, 5% B
2.81	Oil	Center	46	46	12% F, 60% B	10% F, 60% B
2.81	Oil	Midway	47	48	2% F, 50% B	2% F, 50% B
2.81	Oil	0.9 radius	50	54	2% F, 40% B	1% F, 25% B
2.81	Water	Center	50	53	1% F, 40% B	1% F, 35% B
3.81	Oil	Center	42	40	15% F, 75% B	15% F, 75% B
3.81	Oil	Midway	47.5	45+	5% F, 80 to 85% B	10% F, 75% B
3.81	Oil	0.9 radius	51	52	1% F, 40% B	1% F, 40% B
3.81	Water	Center	46	48	5% F, 60 to 65% B	5% F, 65% B

*F = ferrite; B = bainite.

Case V – Delayed Quench

A part has a minimum cross section of 0.5-in. diameter. It is desired to make the part from 86 B 40, and a water quench is necessary to get the specified hardness of C-50 throughout the larger sections. But in so doing quench cracking occurs. To avoid this it is desired to delay the quench – that is, cool in air for a while before quenching in water. How long?

On the quenching diagram for 86 B 40 shown in Fig. 2, a line *A-B* is drawn vertically from the 0.5-in. diameter position on the left-hand portion of the diagram to intersect the curve marked "*Center and Midway (Air Cooled)*". (The cooling rates at the surface and center of bars up to about ¾-in. diameter are almost the same.) Reading horizontally from this point of intersection, Point B, it may be seen that austenite does not start to transform (to ferrite) for nearly 1 min. after taking the part from the furnace; even after 80 sec. only 1% of the structure would be ferrite. Thus the part could be held in still air for 60 to 80 sec. before quenching in water, and this would help to eliminate quench cracking.

Case VI – To Avoid Low Impact Properties

Difficulty has been encountered in meeting impact test requirements on oil quenched and tempered bars in 1 to 5-in. sizes. Such low impact values are frequently associated with mixed structures containing pearlite. In oil quenching the five grades 4140, 5140, 86 B 40, 4340 and 9840, what section sizes, if any, should be avoided with each grade in order to minimize poor impact test results?

No difficulties should be encountered with the 4340 and 9840 steels, since their diagrams (to be published in the April and May issues of *Metal Progress*) are similar to the 86 B 40 grade (Fig. 2) and show that pearlite does not form during oil or water quenching.

The use of 5140 steel (as shown in the data sheet, p. 96-B) would probably be inadvisable in sizes above 1 to 1.5 in., since pearlite forms at the center and midway locations in bars slightly above 1-in. round and increases rapidly in amount as the section size increases.

Figure 1 for the 4140 grade indicates that pearlite will not be formed at the center location in sizes smaller than approximately 3¾-in. diameter or at the midway location in sizes smaller than 4¼ in.

Summary

The above illustrates some of the uses of quenching diagrams and will probably suggest others to the reader. They appear to have particular application where certain microconstituents or combinations of constituents are known to be detrimental and are to be avoided, and in applications where uniformity of structure is particularly desirable.

In using the diagrams, consideration must be given to the quench. The diagrams were derived for conditions involving moderate motion during quenching (resulting in a severity of quench of H = 2.0 for water quenching and H = 0.5 for oil quenching). Obviously, if there is no motion within the medium, or if the motion is very strong, the diagrams would need to be modified accordingly.

Applications of Furnace Atmospheres

*By CLARENCE E. PECK**

Prepared atmospheres are specified for bright annealing, bright hardening and for carburizing or carbo-nitriding of all varieties of plain and alloy steels, and suggestions given (devised from experience) as to the atmospheres conventionally used, their dew points and their carbon "potentials". (J2k; CN, AY, TS, SS)

ACCURATE CONTROL of the composition of the atmosphere within a heat treating furnace is universally recognized as an important part of the production of uniformly high quality in metallic parts. Aside from the many important uses in the nonferrous industry – which will be described in a later article – the major advantages in the heat treatment of steel include one or a combination of the following: control of carbon at the surface (restoration, maintenance, or addition), introduction of nitrogen to the surface, and prevention of oxidation, coloring or scaling. It requires no argument to establish that these advantages will avoid much expense, formerly thought unavoidable, in pickling, buffing and cleaning, not to say the grinding or machining away of unsuitable surface metal.

Mr. Vaughan's paper starting on p. 93 of last month's *Metal Progress* described six basic atmospheres, while I will attempt to review their important applications. Three other papers† read before the Industrial Heating Equipment Association's session at the last National Metal Congress will consider at some length the methods and equipment for controlling these atmospheres accurately and safely. They will appear in *Metal Progress* in April.

For ready reference, it is well to repeat the names of the basic types of atmospheres:

No. 1 – Completely burned fuel gas (exothermic).

No. 1A – Completely burned fuel gas with CO_2 and H_2O removed (exothermic).

No. 2 – Partially burned fuel gas (exothermic).

No. 2A – Partially burned fuel gas with CO_2 and H_2O removed (exothermic).

No. 3 – Partially reacted or cracked fuel gas (endothermic).

No. 4 – Completely reacted fuel gas (endothermic).

No. 5 – Dissociated ammonia.

No. 6 – Partially burned dissociated ammonia.

No. 6A – Completely burned dissociated ammonia.

We will now discuss in some detail the important applications of such atmospheres to iron and steel.

Bright Annealing of Low-Carbon Steel

Strip, bar, wire and fabricated parts in wide variety may be bright annealed in partially burned fuel gas, with the exothermic generator set to give a high percentage of reducing com-

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†This paper, as the others, should be considered as the product of the Industrial Heating Equipment Association. The present writer wishes particularly to acknowledge several sources of information in preparing this summary: The research and development reports of Westinghouse Electric Corp.; publications and photographs from General Electric Co., Surface Combustion Corp., Lindberg Engineering Co., Electric Furnace Co., Holcroft and Co., and Leeds and Northrup Co.

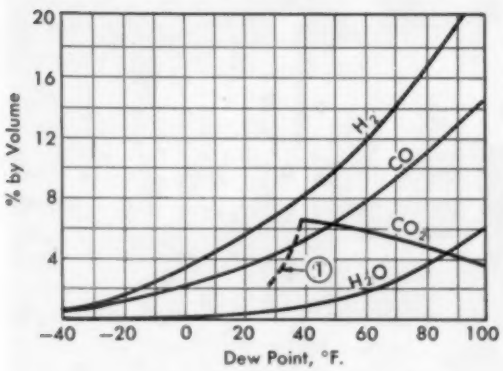


Fig. 1 — Curves Drawn From Experience With the Annealing of Heavy Furnace Loads of Low-Carbon Steel, Showing Minimum Amounts of Hydrogen Necessary to Prevent Discoloration as They Vary With Dew Point, and the Maximum Amounts of CO to Avoid Etching or Soot Deposition. Dotted curve 1 for CO_2 is drawn on the assumption that the gas components in the drier atmospheres will react with each other so as to increase the H_2O content and the oxidizing tendency in the 1100 to 700° F. range

ponents (Atmosphere No. 2). Other atmospheres of a purified exothermic type or those derived from anhydrous ammonia are also suitable but rarely used because of the high operating cost and the more elaborate and expensive equipment required.

The rich exothermic atmosphere commonly used changes in composition with the temperature of the furnace. (Most of the water vapor is removed before the atmosphere enters the furnace.) In addition, this atmosphere has an oxidizing tendency at the lower temperatures, so care must be exercised while the steel is cooling. This is particularly necessary on heavy charges which cool slowly, as occurs in bell furnace annealing. Water vapor is the principal component which can be controlled in quantity when necessary to insure bright annealing.

When the water available for cooling the gas as it leaves the generator is over 60° F., the actual dew point of the atmosphere will be 70 to 75° F. In general, Atmosphere No. 2 of the rich exothermic type with dew points of over 70° F. can discolor steel, due to the oxidizing action of water vapor as the steel slowly cools from 1100 to 700° F. The higher dew points can be tolerated in continuous furnaces with fast cooling cycles without apparent discoloration of the work, but this operation may be marginal and it is better practice to cool the gas further to a lower dew point.

In fact, this is absolutely necessary where cold water is not available the year round; under such circumstances the atmosphere is cooled to dew points of 40 to 45° F. by refrigeration. This is low enough to insure bright annealing even with appreciable variations in the reducing properties of the gas, despite the chance that the cooling water may be warm during the summer. The partially dried (refrigerated) gas also prevents condensation in the cooling chambers of the furnace — a serious problem when the dew point of the gas is higher than the local temperatures of the cooling jackets.

Although CO_2 and water vapor do not need to be thoroughly removed for the bright annealing of low-carbon steel, there are practical limits to the amount of water vapor which can exist in the furnace during slow cooling of large batches of steel if discoloration, bluing or heavier oxidation is to be avoided, and the permissible amount depends on the reducing power of the atmosphere as related to the proportions of hydrogen and carbon monoxide simultaneously present. Figure 1 shows an approximate relation between these factors, based on experience with large batches of low-carbon strip.

Take an atmosphere with 40° dew point. If the hydrogen is less than 8% by volume, oxidation or some discoloration may be expected. Furthermore, for a given dew point (say 40° F.), if the CO content is greater than the value shown on the curve (5.5%), the steel surface may etch or some soot deposit during slow cooling. Conversely, for a given value of CO as indicated on the curve, if the dew point of the gas is less than the value of dew point indicated, then some etching or soot deposition may be encountered.

Usually etching or soot results from a gas too high in CO as compared to its dew point (or to too dry a gas when compared to its CO analysis). It should be emphasized that the practical limits shown on the curve apply principally to the relatively slow cooling of large batches of steel. When continuously annealing strip, wire, tubing or similar long, light items, wider latitudes are possible without evident oxidation or etching, since the time at the temperatures of reaction is relatively short; no visual action occurs even though the gas atmosphere is potentially capable of damage between 1100 and 800° F. Rich exothermic Atmosphere No. 2 is approximately in equilibrium with low-carbon steels at normal annealing temperatures and hence there is no measurable change of carbon. It should be remembered, however, that this atmosphere is

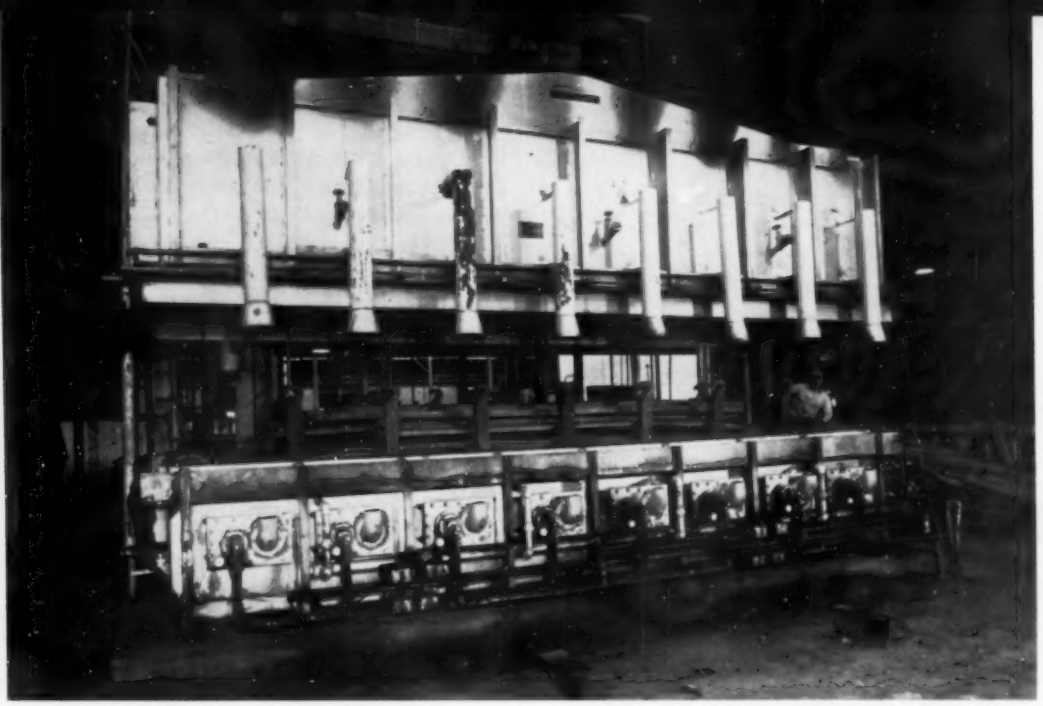


Fig. 2 – Rectangular Bell Annealing Furnace for Heat Treating Various Alloy or Carbon Steels Without Oxidation or Decarburization. (Courtesy of Westinghouse Electric Corp.)

definitely decarburizing to medium-carbon and high-carbon steels and to various alloy steels.

Bright annealing (no discoloration) of low-carbon steels in rich exothermic atmospheres produced from a fuel gas containing sulphur is possible as long as the sulphur content of the fuel gas itself does not exceed 20 to 30 grains per 100 cu.ft. This means scrubbing out most of the sulphur before the fuel gas enters the generator. Manufactured gases or coke oven gases may contain up to several hundred grains of sulphur per 100 cu.ft. before they are cleaned up.

Bright Annealing of Tin Plate

Annealing of tin plate (cold rolled strip) in rich exothermic gas should be done in Atmosphere No. 1A (purified lean exothermic gas) rather than in Atmosphere No. 2. A more uniform surface will result and a smoother deposit in the electrolytic tinning line.

A refinement now used is a further purification of the gas by eliminating the CO and producing a nitrogen gas with about 7% H_2 and only a trace of CO and CO_2. The higher quality in the product justifies the more elaborate and expensive atmosphere conversion and purifying equipment in this application where large tonnages are annealed in both batch and continuous annealing furnaces.

Annealing High-Carbon Steels

Since high-carbon steels (plain and alloyed) must be annealed within a well-defined region a little above the critical range and held many hours, the atmosphere must be practically "neutral" to prevent any loss of carbon from high-carbon steels or any gain of carbon in medium-carbon alloy steels.

Atmosphere No. 1A, set for 3 to 4% CO and approximately the same amount of H_2, has been found quite suitable for long-cycle annealing of high-carbon steels without oxidation or decarburization. Experience has indicated that it will overcome the inevitable oxygen infiltration which must be compensated for by some chemically active constituents in the atmosphere. In other words, it is not desirable to have the atmosphere too inert, but only relatively inert.

From a practical standpoint, an atmosphere in true equilibrium – absolutely neutral – never exists in actual annealing furnaces containing large amounts of hot steel, or through the entire temperature range wherein such masses must be heated up and cooled down.

Nevertheless, atmosphere is required for annealing high-carbon and alloy steel which does not change chemically nor react with the work through a wide temperature range.

At first glance it would seem that 100% nitrogen would be satisfactory, but experience shows that under these circumstances, the steels both decarburize and oxidize. Experience also

shows that high CO alone is not good; intergas reactions form a soot. High hydrogen alone has an extreme tendency to decarburize when relatively small amounts of water vapor are present. Moderate amounts of CO and H_2 together give an excellent compromise and experience has indicated that Atmosphere No. 1A with 3 to 4% CO and about the same amount of H_2 gives an inert gas which is still active enough to overcome any contamination by substances which otherwise would cause oxide to form on hot steel. The gas itself is low enough in CO, H_2 and H_2O so intergas reactions are very small, and the gas reactions with the metal – if they are theoretically possible – proceed at such a very slow rate that their effects are negligible.

An example of a "neutral" atmosphere is taken from the bright annealing of 1.25% carbon steel strip. After steel reaches an actual temperature of 1350° F., it is held there for 8 to 10 hr. before starting a slow cooling cycle. The microstructure is completely spheroidized and, insofar as the effect of the atmosphere is concerned, there is no evidence of decarburization or intergranular oxidation. A sample of the atmosphere drawn from the furnace analyzed about 4% CO and 6% H_2, with a dew point of about –30° F.

Annealing of Toolsteel Bar Stock

Carbon and alloy toolsteels usually require higher annealing temperatures than other carbon steel strip, rod and wire. Since the rates of possible reaction between atmosphere and steel surface are much faster at these higher temperatures, it is of great importance to use an atmosphere which is chemically stable within itself, and also which is about neutral toward the steel at the high temperature, so that there is no change in the carbon at the steel's surface.

To meet this requirement, experience has shown that Atmosphere No. 1A with a generator set to give around 4% CO and 5 to 6% hydrogen will be satisfactory.

Hot rolled stock of either coiled rod or straight bar, cleaned of mill scale by pickling, and which has a decarburized skin anywhere from 0.005 to 0.010 in. deep can be successfully annealed without any additional decarburization in Atmosphere No. 1A. In other words, the effect is to anneal while maintaining the status quo, which is usually impossible without additional decarburization when annealing in air or in products of combustion, or by packing the work in iron chips. Annealing without additional decarburization naturally presumes the proper furnace equipment to maintain the required atmosphere.

Atmosphere annealing of alloy or toolsteel rod and bar stock without first removing mill scale and without additional decarburization is now being done successfully on a commercial basis. A furnace with a rectangular bell, having an outer oil seal and no inner cover, heated with gas-fired radiant tubes located both in the bell and in the base, is shown in Fig. 2. Atmosphere No. 1A is again suitable, except that in some instances the CO content should be increased a little (to about 6%) with corresponding increase in hydrogen. This combination is reducing enough at temperatures well below the critical range of these steels so the products of reaction between atmosphere and mill scale can be purged out before the steel is heated up to its critical range. These reaction products are H_2O and CO_2, both of which would be decarburizing to the higher carbon steels at temperatures at and above the critical. With this atmosphere and furnace equipment, one can also add small amounts of natural gas or propane and thus recarburize the surface layer to the original analysis.

Silicon Steels

This class of steel varies widely in silicon content and in the annealing temperatures used. Also due to differences in time cycles, the atmosphere requirements are not necessarily as rigid when handling the material continuously in strip form as in batches of coils or sheets.

The steels with lower silicon content, which can be annealed at lower temperatures, usually require an atmosphere which merely prevents oxidation. Atmosphere No. 2 is suitable. At these lower temperatures the rates of any possible reactions are probably very slow, and the possibility of carbon pickup, or oxidation of silicon by water vapor is too small to make any serious difference in the magnetic properties.

When working with the higher silicon electrical steels, the principal problems from an atmosphere standpoint are the prevention of oxidation and carbon pickup.

Reactions between atmosphere and carbon in the steel are on the opposite end of the scale when compared with the annealing of high-carbon and alloy carbon steel. High-carbon steel requires that the atmosphere contain sufficient "carbon potential" to prevent transfer of carbon from metal to atmosphere. Electrical silicon steels require one which prevents *any* gain in carbon, and the carbon is very low to start with

– on the order of 0.005% or less. Thus, atmospheres which normally decarburize the higher carbon steels at elevated temperatures will carburize the very low-carbon silicon steels, particularly above 1600° F.

Since the high-silicon steels are annealed at 1800 to 2100° F., the possible reaction rates are relatively fast, and if the atmosphere has a slight carburizing tendency, enough carbon may be picked up to affect the desired magnetic properties. For this reason, atmospheres containing CO or a trace of methane (or both) are unsuitable. For such high temperatures, Atmosphere No. 2 would therefore be unsuitable. Although atmospheres containing CO may ordinarily be neutralized with water vapor, this expedient is not available since water vapor oxidizes the silicon and also the iron itself at high temperatures. Therefore, the required atmosphere should be very dry and free of any carbonaceous gases such as CO or CH_4.

To meet these requirements, the following commercial atmospheres may be used:

1. Pure dry high-hydrogen gases such as dissociated ammonia (Atmosphere No. 5).
2. Pure dry hydrogen-nitrogen mixtures such as those obtained from burning and then drying dissociated ammonia. No. 6A, set for almost complete combustion, is one possibility.
3. Practically pure dry nitrogen, such as that obtained from complete burning of fuel gas and subsequent removal of CO_2 and water vapor (Atmosphere No. 1A, set for practically complete combustion with negligible CO content).

Possibilities No. 2 and 3 above are cheaper and more commercial for hot rolled high-silicon sheets, where the optimum results possible with high-hydrogen gases are not readily attained on stacks of wide flat sheets and where, from a practical standpoint, it is difficult to remove or control water vapor locally inside the pack, arising from moisture trapped in the stacks.

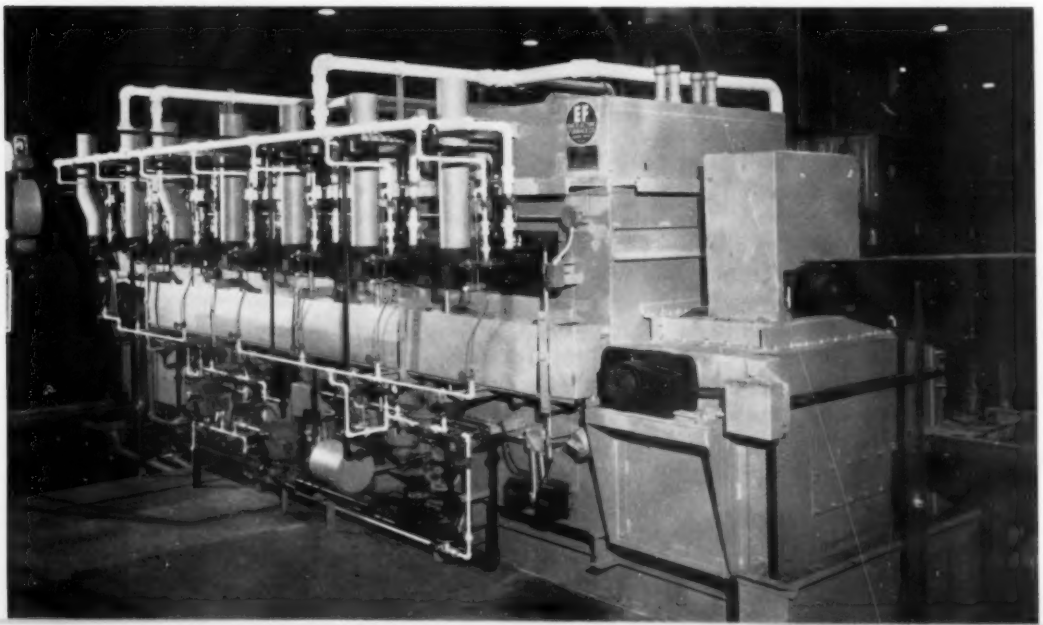
Stainless Steels

The requirement for a true bright anneal on the high-chromium and the chromium-nickel stainless steels is an atmosphere which contains no oxygen, practically no H_2O, no CO, no CO_2 and no sulphur. In other words, oxygen (either in free or combined form) cannot be tolerated, else discoloration will occur.

Pure dry hydrogen or dissociated ammonia will bright anneal stainless steel, but only under operating conditions where all possible traces of oxygen or water vapor can be kept out of the atmosphere surrounding the work. From a practical standpoint, this presumes a closed muffle, sealed and constructed in such a way that no leakage is possible. Experience has shown that if the muffles are not extremely tight, oxygen containing impurities can "back diffuse" through any crack in the muffle and cause discoloration – even though there is a reasonably good pressure inside the muffle. For this reason, it is desirable to use the hydrogen atmosphere both inside and outside of the muffle and thus obtain a "double muffle" effect.

Due to these practical limitations, commercial bright annealing of stainless has been limited to strand annealing of wire, rod and very narrow

Fig. 3 – Radiant Tube, Gas-Fired, Cast Link Belt Conveyer Furnace With Dual Quench for Hardening Miscellaneous Parts. (Courtesy Electric Furnace Co.)



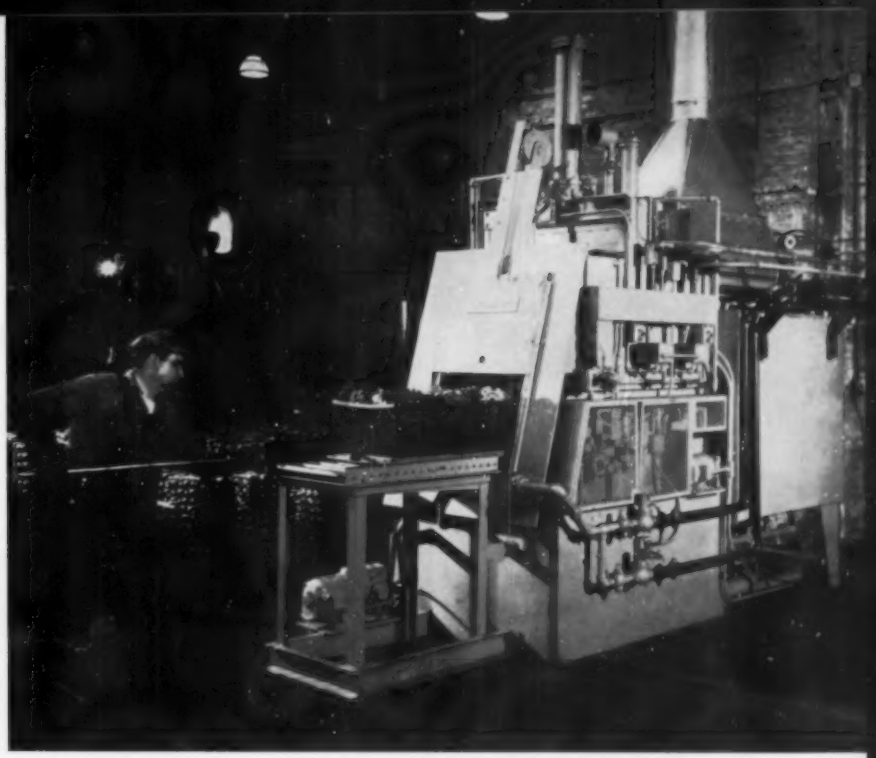


Fig. 4 – Batch Type, Gas-Fired, Vertical Radiant Tube Furnace Suitable for a Wide Variety of Operations. (Courtesy Lindberg Engineering Co.)

strip where the muffle itself is a tube of relatively small diameter, with comparatively thick walls.

Where really bright annealing is not required (a thin film of very stable oxide can be tolerated) or where it is desirable to limit oxidation below that which must be pickled off before further fabrication, the fuel gas atmospheres, particularly Atmosphere No. 1A, will do a satisfactory job.

For scale-free (not bright) heat treatment of the chromium-iron stainless steels, the endothermic types of atmospheres such as No. 3 or No. 4 are suitable. Also Atmospheres No. 1A or 2A are suitable. However, Atmosphere No. 2 will result in excessive oxidation during the longer cycles at the higher temperature ranges of heat treatment (1800 to 2100° F.) and does not minimize oxidation as well as the endothermic types.

There is little choice among the principal controlled atmospheres, commercially available, when it comes to scale-free (not bright) heat treatment of the Ni-Cr stainless or heat resisting steels, as far as surface oxidation is concerned. The type of oxide formed under these conditions seems very stable and the amount and characteristics of film do not seem to vary much when using a wide range of composition in the protective atmospheres.

It has been found that the dry dissociated ammonia will embrittle extremely thin sections of some of the stainless steels. Surgical needles and other very thin sharp sections require a pure dry hydrogen atmosphere rather than dissociated ammonia. Apparently enough nitrogen is absorbed to lower the ductility of the metal, and the only remedy is to keep nitrogen out of the atmosphere. It is of interest to note that this is not noticeable on heavier sections, and also that the conventional fuel gas atmospheres (all of which contain nitrogen) do not embrittle stainless – probably due to opposing reactions which form a stable oxide film.

Bright Hardening

If a part made from high-carbon or alloy carbon steel can be heat treated without decarburization, carburization or oxidation, such a close control of surface conditions avoids finish machining or grinding and also eliminates the need for cleaning, sand blasting or descaling. To maintain this balance where carbon is neither lost or added to the surface requires a furnace atmosphere which is approximately in equilibrium with the carbon content of steel at the temperature of heat treatment. Long experience by a considerable segment of the industry (as well as considerable development work) has shown that the most economical and suitable atmosphere for this requirement is reacted endothermic gas, such as Atmospheres No. 3 and 4 which are practically "balanced" or in equilibrium since there is very little interaction between the constituents over a wide range of temperature.

Since the atmosphere itself is balanced, the

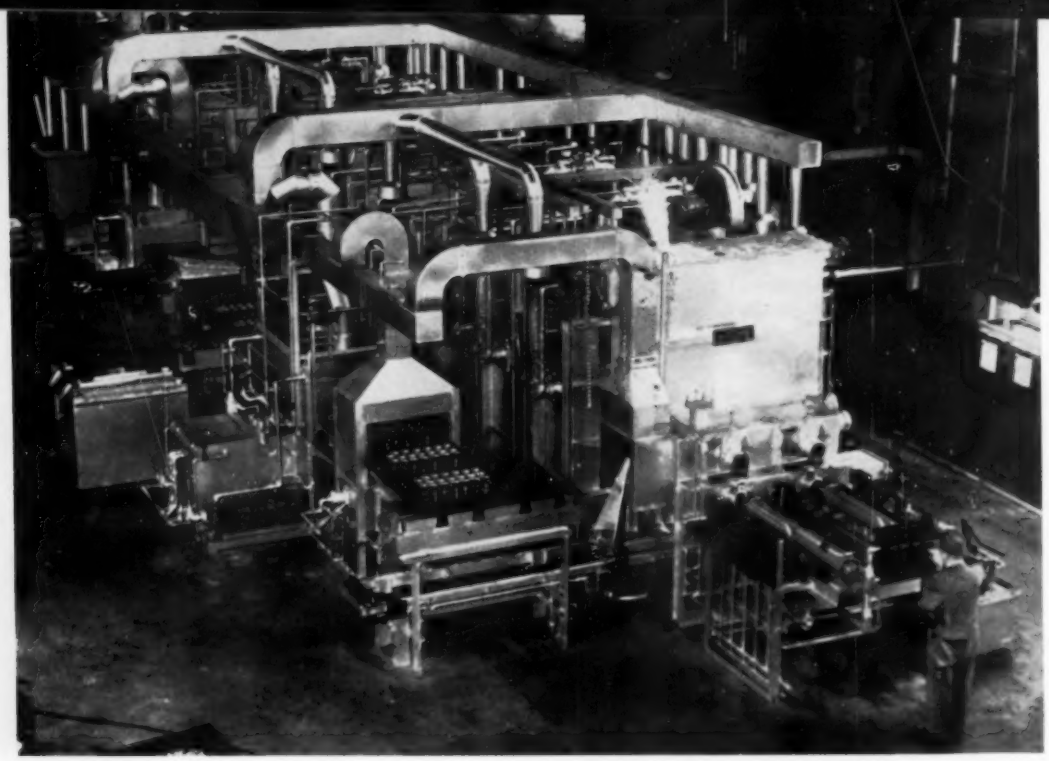


Fig. 5 – Continuous Tray-Pusher Type Furnace Carburizes, Quenches, Washes and Dries Automatically in a Closed Circuit Requiring Only One Loading on the Tray. (Courtesy Holcroft & Co.)

problem is narrowed down to one of adjusting it to be in approximate equilibrium with the carbon content of the steel. This is done by adjusting the air-gas ratio entering the generator to produce an endothermic atmosphere with a specific dew point and limited amounts of CO_2 and residual methane. When in equilibrium with steels in the medium-carbon range, the dew point is well above freezing and the CO_2 is from 0.5 to 2.0%. For atmospheres in equilibrium with high-carbon steels, the dew points are well below freezing and the CO_2 is usually less than 0.5%.

Because the atmosphere is easily adjusted to give various carbon potentials, it can be applied to bright hardening over a wide range of temperatures, without excessive carburization or decarburization of the heat treated product.

In general, for the large group of steels hardened in the neighborhood of 1450 to 1550° F., the carbon potential does not need to be nearly as high as for the more special steels requiring much higher hardening temperatures. In these lower temperature ranges, a wider variation in dew point or carbon potential is permissible, because the rates of reaction with carbon in the steel (particularly in the medium-carbon steels) are relatively slow and departures from true equilibrium are not serious. Another important factor is that the total time the steel is at its critical temperature is usually a fraction of an hour rather than hours. Thus, the combination of lower temperatures, shorter times and accompanying slower reaction rates allows a considerable degree of latitude in the constituents of the atmosphere.

Experience also has shown that when hardening in the lower temperature ranges, the amount of furnace impurities can be greater without danger to the product. If much oxygen enters through doors and other openings, the operator can use a gas of higher carbon potential. This is especially true in short cycle hardening, where the maintenance of an exact equilibrium is unnecessary.

A Word of Caution – The reacted endothermic atmospheres, while balanced with themselves, are chemically active. In the higher temperature ranges or for longer times, or both, marked changes in carburization (or decarburization) may result. Under these conditions the desired carbon equilibrium must be maintained within closer limits and the endothermic gas itself must be relatively dry.

Table I shows a range of practical values of dew point of reacted endothermic atmospheres for approximate equilibrium with various carbon contents of steel. Note the broader range of dew point permissible at lower temperatures and in the medium-carbon range. At the higher temperatures, such as required for hardening of tool-

Table I – Dew Point Limits for Neutral Hardening in Endothermic Atmospheres
(Also a Measure of Carbon Potential as a Carrier Gas)

Temperature	Carbon Content of Steel Under Treatment							
	0.3-0.4%	0.4-0.5%	0.5-0.6%	0.6-0.7%	0.7-0.8%	0.8-0.9%	0.9-1.0%	1.0-1.10%
1450-1550	65-80	57-65	55-60	53-56	50-53	47-50	44-47	43-45
1550-1650	50-60	45-53	40-45	36-40	32-36	28-32	25-28	23-25
1650-1750	40-50	35-40	32-35	28-32	25-28	23-25	20-23	18-20
1750-1850	32-38	28-33	26-29	23-25	20-23	18-20	16-18	15-16
1850-1950	28-33	25-28	23-25	20-23	17-20	16-18	14-16	13-14
1950-2050	25-28	22-25	20-23	17-20	15-17	14-15	13-14	12-13
2050-2150	22-25	20-23	18-20	16-18	15-16	14-15	12-13	11-12
2150-2250	18-20	16-19	15-17	15-16	14-15	13-14	11-12	10-11

steels, lower dew points are necessary, and the permissible variation is much narrower.

Where temperatures are in the higher ranges, as in heat treating certain toolsteels and high speed toolsteels, the high carbon potential available with *dry* reacted endothermic gas is definitely required. However, even when this atmosphere is produced in gas from the generator, the carbon potential actually existing in the furnace is usually considerably less, due to the action of impurities from the refractories (where metal muffles are not used) and to infiltration of oxygen. To avoid difficulties a few percent of natural gas or propane should be added to the atmosphere to fortify it. If larger additions seem to be necessary to establish the correct carbon potential, then equilibrium cannot be easily maintained. Relatively small changes in temperature and time can cause excessive carburization and soot deposition. *Neutral* hardening conditions no longer exist. Such circumstances usually indicate an insufficient volume of atmosphere to the furnace or leakage of air resulting in excessively high dew points.

The high H_2 and CO content of endothermic atmospheres (usually 35 to 40% H_2 and 18 to 20% CO) permit one to use the dew point as a good measure of the carbon potential. A considerable range of dew point values is possible to define a considerable range of values of carbon equilibrium. Carbon potentials in atmospheres such as No. 1A and 2A (purified high-nitrogen types), much lower in H_2 and CO, are much more sensitive to variable action as the dew point varies. They must be extremely dry to maintain a reasonably high carbon potential; for this same reason their carbon potential is reduced when moisture forms in the furnace for any reason. Therefore such atmospheres are not very suitable for neutral hardening or recarburizing, particularly of the higher carbon grades of steel.

Bright Hardening High-Alloy Steels

If some discoloration or slight oxidation is permissible, the reacted endothermic Atmosphere No. 4 will give satisfactory results (insofar as control of carbon content is concerned) when "bright hardening" the high-carbon, high chromium steels and the ferritic stainless steels.

However, where *really bright* surfaces are required, all oxygen bearing constituents must be completely eliminated, and the dew point of the atmosphere *in the furnace* must be very low. This can only be insured in furnaces with gas-tight metallic muffles containing dry dissociated ammonia or dry hydrogen. These steels can also be carburized, under the conditions mentioned above, after fortifying the atmosphere with a few percent of natural gas or propane.

Gas Carburizing

Gas carburizing is an operation which could easily form the topic of an entire conference. From the standpoint of *application*, the factor of outstanding importance for prepared atmospheres is the use of the most efficient carrier gas in large enough quantity to maintain adequate static pressure inside the furnace, and thus neutralize and minimize the effects of infiltration. We can thus start out with a certain "plateau" of carburizing potential in the furnace (such as equilibrium with medium carbon steels) and from this plateau the required carbon potentials for fast, clean, soot-free gas carburizing can be attained by adding relatively small amounts of hydrocarbons – usually natural gas or propane. If these conditions do not exist in the furnace, then the desired carburization requires considerably larger additions; conditions then are relatively unstable and an excessive amount of carbon will deposit on all parts of the furnace as well as on the work itself.

Table II – Atmospheres Suitable for the Heat Treatment of Steels

Material and Process	Atmospheres Which Will Give Desired Result	Atmospheres Commonly Used
Bright Annealing of Ferrous Metals		
Low-carbon steels	1A, 2, 2A, 5, 6, 6A	2
Tin plate	1A (with CO removed)	1A with CO removed
Medium-carbon steels (no decarburization)	1A, 2A, 5, 6, 6A	1A
High-carbon steels (no decarburization)	1A, 2A, 5, 6, 6A	1A
Alloy steels, medium and High-carbon (no decarburization)	1A, 2A, 5, 6, 6A	1A, 2A
High speed toolsteels, including molybdenum types (no decarburization)	1A, 2A, 5, 6, 6A	1A
Stainless steels and chromium-irons (bright)	5	5
Stainless steels and chromium-irons (discolored, but no scale)	2A, 3, 4	3
Cr-Ni stainless steels (bright)	5	5
Cr-Ni stainless steels, (discolored, but no scale)	1, 1A, 2, 2A, 3, 4	1, 2
High-silicon steels (high-temperature anneal)	1A, 6	1A, 6
Silicon steels (low-temperature anneal)	1A, 2, 5, 6, 6A	2
Bright Hardening and Tempering		
Medium-carbon steels	1A, 2A, 4, 5, 6, 6A	3, 4
High-carbon steels	1A, 2A, 4, 5, 6, 6A	4
Alloy steels, medium and high-carbon	1A, 2A, 4, 5, 6, 6A	4
High speed toolsteels, including molybdenum types	2A, 4, 5, 6, 6A	4, 5 (fortified with hydrocarbon)
Tempering all ferrous metals	1A, 2	2
Carburizing; Carbo-Nitriding; Nitriding		
All ferrous metals (carburizing)	2A, 4 (plus hydrocarbon addition)	4 plus hydrocarbon addition
All ferrous metals (carbo-nitriding)	2A, 4 (plus ammonia plus hydrocarbon)	4 plus ammonia plus hydrocarbon
Stainless steels	4, 5 (plus hydrocarbon)	5 plus hydrocarbon
Nitriding steels	Ammonia	Ammonia

The previous comments on the desired properties of the reacted endothermic Atmosphere No. 4 for neutral hardening apply directly to the preparation of an efficient carrier gas for gas carburizing. Table I indicates the approximate carbon potentials and dew points for Atmosphere No. 4. It has low CO_2 and H_2O and high H_2 and CO (as compared to the purified nitrogen gases such as Atmosphere No. 1A and 2A) and is the most practical and efficient carrier gas available at the present time.

These same basic requirements are equally as important in related carburizing processes, such as in carbon restoration and homogeneous carburizing.

Carbo-Nitriding is basically gas carburizing with ammonia added to the atmosphere. The steel acquires a combination case of carbon and nitrogen. Case depths are usually shallower and temperatures 100 to 200° lower than for gas carburizing. As mentioned above, the most important factor (from an atmosphere application standpoint) is to use an efficient carrier gas in sufficient quantity to maintain adequate static pressure in the furnace. When this is done, the amount of ammonia and hydrocarbon addition required for a given depth and quality of surface hardening is only a fraction of that required for less efficient conditions.

Since carrier gas is usually a lot cheaper than ammonia or hydrocarbons, the importance of the proper carrier gas in sufficient volume is quite evident. Also the reproducible and uniform quality of ammonia and hydrocarbon becomes less of a worry with the attendant uncertainty as to the effect of variable compositions on reaction rates and chemical changes.

Perhaps the best summary of what has gone before is Table II, a listing of the atmospheres which have been and can be used for the wide range of heat treatment of steels, and notations of those which are customarily used.

FOR chemical processing OF ANY METAL... turn to Turco...FIRST!

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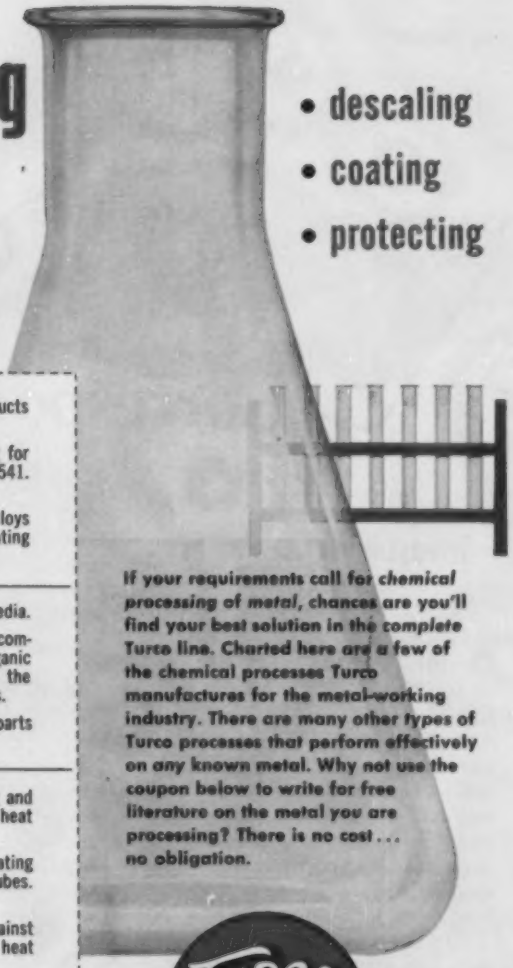

ALUMINUM	**DESCALING:** Complete line of deoxidizing and polishing products for all alloys of aluminum. **COATING:** Economical and "quick fixing" conversion coating for application by spray, dip or hand methods. Approved to MIL-C-5541. Insures paint adhesion, stops aluminum corrosion. **PROTECTION:** Alkali-removable protective film for aluminum alloys both during storage (in plant and outdoor) and during fabricating practices.
STEEL	**DESCALING:** Complete line of alkaline and acid descaling media. **COATING:** Full line of iron, zinc and manganese phosphate compounds to provide a tight coating for better adhesion of organic finishes and for oil absorption. These materials all meet the various requirements of applicable government specifications. **PROTECTION:** Versatile group of products for protection of parts from the elements.
TITANIUM	**DESCALING:** Approved and accepted process for conditioning and removing scale from all current titanium alloys, both after heat forming to 1150° F. and heat treating to 1750° F. **COATING:** Acceptable anti-galling and seizing conversion coating for the major alloys of titanium. Also used as base for lubes. Requires no post-heat treatments. **PROTECTION:** Easily removable coating to protect titanium against tightly adhering scale up to 1600° F. during hot forming or heat treating.
STAINLESS STEEL	**DESCALING:** Process for completely removing heat scale from various alloys (including 17-7 PH). **COATING:** Easily removable coating to protect stainless steel against tightly adhering scale up to 1600° F. during hot forming or heat treating.
MAGNESIUM	**DESCALING:** Non-electrolytic alkaline process for removing previous chrome pickle films as well as oily substances often found on magnesium. **COATING:** One-package powdered product which, when in solution with water, replaces Dow #17 treatment. Requires no mixing of chemicals. Eliminates chance of human error. **PROTECTION:** Single-package touch-up liquid to produce coatings equal to Dow #18 treatment. (Note: All magnesium processes mentioned above are approved for use by Magnesium Department, Dow Chemical Co.)

If your requirements call for *chemical processing of metal*, chances are you'll find your best solution in the *complete* Turco line. Charted here are a few of the chemical processes Turco manufactures for the metal-working industry. There are many other types of Turco processes that perform effectively on *any* known metal. Why not use the coupon below to write for free literature on the metal you are processing? There is no cost... no obligation.

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Correspondence . . .

Investment X Process

MANCHESTER, ENGLAND

In Professor Grant's article on "Recent Developments in the Art of Precision Casting" in *Metal Progress* for September 1956, he states, when describing the Investment X Process (p. 116), that a pattern is made of successive layers of refractory on a disposable pattern of wax, and that "the wax is removed by solution in trichlorethylene at room temperature".

This is incorrect. The wax, in fact, is removed by suspending the shell-coated assembly of patterns in hot trichlorethylene *vapor*. An ordinary industrial degreasing plant is used for this purpose, operated at 110° C. (230° F.). The hot vapor dissolves the wax at a rate greater than that at which it expands, and so eliminates mold cracking. It was found that this method of dewaxing would not work with a block type of mold (as opposed to a shell) since the mold would crack during the process. Soaking the mold in trichlorethylene at room temperature, as suggested by Prof. Grant, proved far too slow.

The dissolved wax drips down into the bottom of the dewaxing bath in solution with trichlorethylene. Periodically the wax is recovered by bubbling air through the solution, which liberates the trichlorethylene. The frequency of recovery is dependent on the percentage of wax present; if this is allowed to become too great (in excess of approximately 80%) then the molds will crack during dewaxing. Ideally, dewaxing and wax recovery should be a continuous and simultaneous operation, so that the proportion of wax in solution is kept at a low level. Wax thus recovered is suitable for reuse for patterns.

Introduction of the Investment X Process resulted in a big improvement in the quality of our castings and a reduction in the scrap percentage. This was partly due to elimination of mold cracks, which previously resulted either in complete breakdown of molds during casting, or the presence of refractory inclusions in the metal.

R. G. NICHOLAS
Manufacturing Engineer,
Process & Rate Dept.
Metropolitan-Vickers
Electrical Co., Ltd.

Steel Going to the Dogs

LONDON, ENGLAND

What may prove to be a new type of eutectic called "scottite" has been found in high speed steel. This constituent is a complex tungsten-iron-chromium-vanadium carbide observed in an unetched specimen from the header and discard in what is believed to be the first cast of high speed steel made in Britain by low-frequency induction melting. The steel was made under the direction of William Kelsey of Inca Steel Co., Sheffield, who suggested that an examination of specimens from various areas of his ingots might be of metallurgical value.

The specimen reproduced here was photographed under high-pressure mercury arc, incident lighting, at 1000× (reduced to 600× in reproduction) by R. W. Shapton, metallurgist of Rotax Ltd., Aircraft Electrical Engineers, London, using a Reichert MeF projection microscope. Preparation was by diamond polishing and I do assure you the specimen was not "doctored".

Critics should be advised that the hind legs are not out of focus – the apparition was in point of fact engaged in covering up its tracks when first observed!

T. BISHOP, Editor
Metal Treatment and Drop Forging

Minor Man-Power Crisis Avoided

NEW YORK

Perhaps much of the worry about young people and their allergy to engineering and science comes from adults rather than the high schoolers. Certainly the Science Award program indicates that a sizable fraction of our high schoolers, and those of top grade also, can build everything from a workable weather sta-

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Man-Power Crisis . . .

tion to aircraft flight instruments.

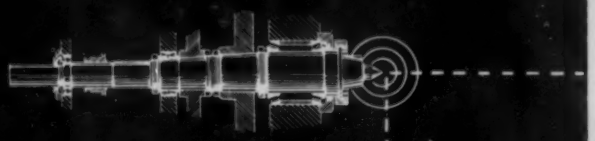
It appears to me that American industry can do a service to these youngsters – to say nothing of itself – by putting these bright youngsters into the right kind of summertime jobs. For example, our Solid Mechanics Laboratory last summer hired Stephen Miller, a 15-year old junior of Teaneck High School as a student assistant. Here was a chance to solve an engineering manpower problem; relatively minor, to be sure.

Stephen, who got straight A's in his math and science, had been thinking of a summer job as a waiter in a nearby restaurant. At the end of the summer, his supervisor reported he was "of substantial assistance" in preparing specimens, assisting in wave propagation experiments and static stress tests, and in reducing data from oscilloscope photographic records. He took on many routine tasks in the laboratory and its photographic darkroom. He learned to use a desk calculator and assisted in computational work.

Stephen, at the beginning of the summer, had no particular ideas as to his future. We now suspect that his summer job has put a career in engineering or science at the top of his list.

HAROLD K. WORK
Director of Research Division
New York University

Cincinnati Sub-ZEROing in
FOR ACCURACY



Shrink fit assembly assures maximum rigidity for spindle bearing raceways of new LeBlond 22 inch 4-bearing spindle.

To assure maximum accuracy for every turning operation, The R. K. LeBlond Machine Tool Company utilizes a Cincinnati Sub-Zero Industrial Chilling Machine in shrink fit assembly of spindle bearing raceways.

This internationally known lathe manufacturer mounts the spindles of its heavy duty lathes in precision tapered roller bearings which run in close tolerance steel raceways. Shrink fit assembly assures that raceways will fit tightly in headstock, perfectly aligned for true spindle operation. In addition to raceways, many other vital components are chilled with Cincinnati Sub-Zero equipment at R. K. LeBlond, in stabilization as well as assembly operations.

A new catalog on the complete line of Cincinnati Sub-Zero equipment for industrial and laboratory use is now available. Write for your free copy or outline your special low temperature requirements.

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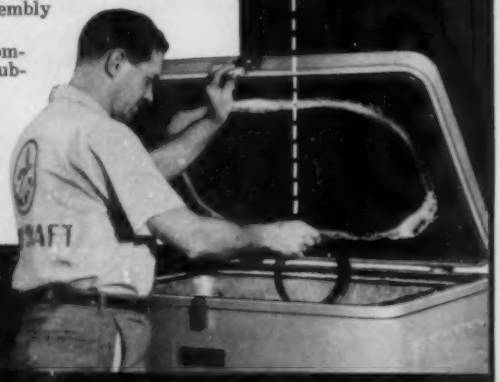

Spindle bearing raceway is placed in Cincinnati Sub-Zero Chilling Unit R-70-10 at LeBlond.

Cincinnati Sub-Zero Products

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Atomic Submarine . . .

(Starts on p. 92)

It is important to emphasize that the superheater leaks do not affect the safe operation of the reactor itself. The possibility of a radioactive sodium leak had been taken into consideration by the designers and adequate containment was provided. Moreover, all central station plants now under consideration which utilize liquid sodium coolants include the further precaution – impossible in a submarine – of a separate intermediate heat exchanger.

Reliable components for central stations are easier to provide. The plants are less subject to rapid load changes and resulting transient stresses. Space permits ready access for examination and repair. Intermediate exchangers should reduce water-side corrosion from radiation-induced decomposition products of water.

Experience with the "Seawolf" emphasizes that there is still a great deal we do not know about metallurgy, corrosion, and the construction of heat exchangers. More specifically, this experience has focused our attention on the differences between the requirements of naval and civilian heat exchangers in sodium systems.

Sodium technology for central station nuclear power plants still appears to be one of the most important possibilities. The Atomic Energy Commission has authorized the development of the sodium-cooled system because of its distinct advantages over others, and the promise it holds for economic nuclear power. We are confident that we shall develop the technology to achieve this objective.

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Personal Mention

Eric R. Jette

Richard D. Chapman

ERIC R. JETTE will be the director of the new Union Carbide Research Institute, to be erected near Tarrytown, N.Y. (Completion date is set as spring 1958.) The major work of this new institute, under the administration of A. B. KINZEL, vice-president of research of Union Carbide and Carbon Corp., will be in the field of fundamental scientific research, complementing and extending the research being carried out by Union Carbide's other laboratories.

Until World War II, Dr. Jette was a professor of metallurgy at Columbia University, and before that professor of chemistry at New York University. Then in 1942 he was named associate director of the Chemical Warfare Service Laboratories at Columbia, and two years later joined the staff of scientists at the Los Alamos Laboratory working on the Manhattan Project. Here he was a group leader directing work on determining the properties of the new metal plutonium, the most important and dangerous task assigned to the metallurgists at Los Alamos.

After the war, Dr. Jette stayed on at Los Alamos and continued to direct more intensive research on this metal and its alloys. In addition, as division leader of the chemistry and metallurgy division from 1945 to 1956, he was in charge of the general metallurgical work.

RICHARD D. CHAPMAN, now managing engineer of the metallurgical research department for the engineering division, Chrysler Corp., Detroit, has devoted his professional career to date to this Chrysler division. In 1937, with a degree in chemical engineering from Michigan State College, he enrolled in the Chrysler Institute of Engineering, receiving his master's degree two years later. Beginning in the engineering division's metallurgical laboratory, he worked his way into X-ray diffraction studies and metallograpic work. During the war he served as metallurgical liaison between the Chrysler Tank Arsenal and the Detroit Ordnance District, and in 1945 became a project engineer in the metallurgical research department; in 1950 he received another promotion to supervisor of metallurgical research.

Mr. Chapman is active in several technical societies, is a past chairman of the Detroit Chapter of A.S.M., and has held offices in the American Institute of Mining, Metallurgical, and Petroleum Engineers. He now is chairman of the Transactions Committee. In addition, he finds time to mix his metallurgical activities with music and magic. He is the founder of the Hammond Organ Society of Birmingham, Mich., and has the further distinction of being a semi-professional magician.

John L. Lamont was recently named assistant manager of administration of the Metals Research Laboratories, Electro Metallurgical Co., a division of Union Carbide and Carbon Corp., Niagara Falls, N.Y. Mr. Lamont, who joined Union Carbide in 1929, has been a research metallurgist, senior research assistant, and section leader in the metals research group with the company. He also heads the administrative service department, in addition to his new duties. Mr. Lamont is currently treasurer of the Buffalo Chapter.

Harvey D. Neale, a member of the staff of the Philadelphia sales district, Heppenstall Co., Pittsburgh, received the annual Ring Sales Award from the company for outstanding sales accomplishment.

J. Roy Gordon has been elected executive vice-president of the International Nickel Co. of Canada, Ltd., and the International Nickel Co., Inc., the company's United States subsidiary. Affiliated with Inco since 1936, Mr. Gordon was a vice-president of both companies before his promotion, in addition to serving as general manager of Canadian operations and a director of both the parent company and its United States subsidiary. (A more detailed report of Mr. Gordon's career was published in the September 1953 issue of *Metal Progress*.)

Roy O. Schiebel was recently elected second vice-president, sales and marketing, of the Magnaflux Corp., Chicago. For the past two years, Mr. Schiebel has been sales manager of the company, and prior to that was eastern district and export manager in the New York Office.

Donald H. Turner, a specialist in the melting of refractory metals, has returned to Armour Research Foundation of Illinois Institute of Technology as a supervisor of melting and heat treating services. Mr. Turner was a project engineer, heading consumable electrode arc melting services, with the Foundation until 1954 when he joined Titanium Metals Corp. of America, Henderson, Nev., as a research engineer.

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METALLURGICAL SPECIALISTS

Personals . . .

Robert F. Spillett has been named to the newly created position of New England toolsteel supervisor for Crucible Steel Co. of America, Pittsburgh, with headquarters in Boston. Mr. Spillett joined Crucible in 1937 and until recently was a toolsteel service engineer with the company's toolsteel engineering and development group at the Sanderson-Halcomb Works, Syracuse, N. Y.

Floyd F. Rechlin has accepted a position as project engineer with Solar Aircraft Co., San Diego, Calif. Mr. Rechlin was previously associated with the Alloy Engineering and Casting Co., Champaign, Ill., as field project engineer.

Pierre Coheur, director of the Centre National de Recherches Metallurgiques, Liège, Belgium, has been appointed instructor of general metallurgy, steelmaking and metallography on the science faculty of the University of Liège.

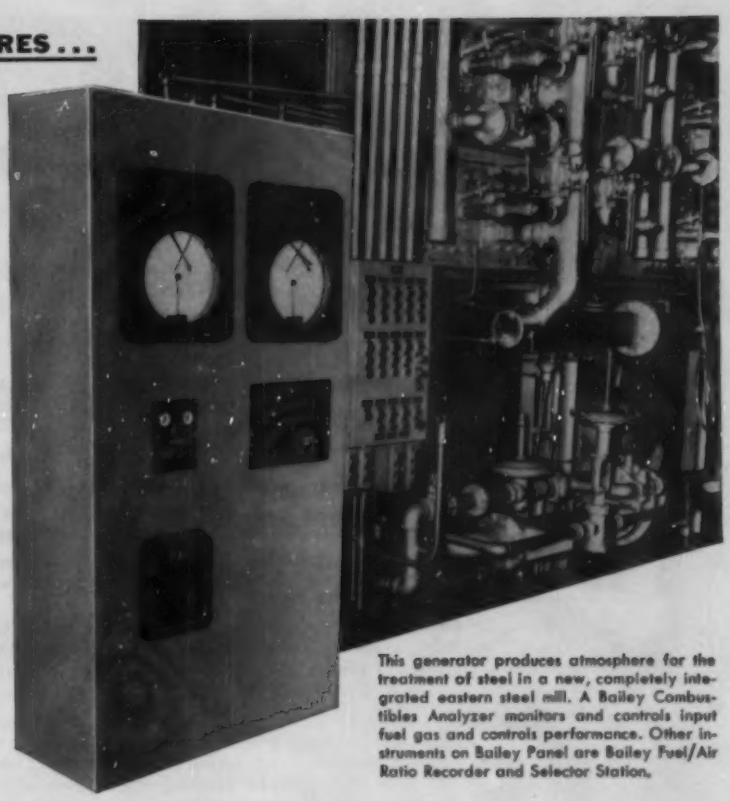
Robert J. Sutton, in addition to his duties as secretary-treasurer, has assumed the responsibilities of director of purchasing for Atkins Saw Div., Borg-Warner Corp., Indianapolis, Ind.

Donald C. Hilty, manager of the research information group, Metals Research Laboratories, Electro Metallurgical Co., a division of Union Carbide and Carbon Corp., Niagara Falls, N. Y., has been appointed vice-chairman in charge of regional meetings of the Institute of Metals Div., American Institute of Mining, Metallurgical, and Petroleum Engineers. Last spring Mr. Hilty was general chairman of the Reactive Metals Conference held in Buffalo under the sponsorship of the A.I.M.E.

Harris M. Sullivan has been chosen as manager of the newly established General Electric Advanced Semiconductor Laboratory in Syracuse, N. Y. The new laboratory will take over and expand the activities in semiconductor research previously performed by the company's electronics laboratory. Dr. Sullivan had been manager of the electronics laboratory since joining General Electric in 1955.

HOW TO CONTROL ATMOSPHERES . . .

BAILEY COMBUSTIBLES ANALYZER



This generator produces atmosphere for the treatment of steel in a new, completely integrated eastern steel mill. A Bailey Combustibles Analyzer monitors and controls input fuel gas and controls performance. Other instruments on Bailey Panel are Bailey Fuel/Air Ratio Recorder and Selector Station.

compensates for variations in gas quality

Whether you are making your heat treating atmospheres out of natural gas or a by-product fuel, variations in gas quality are bound to occur. When this happens, it is impossible to maintain a satisfactory gas-air ratio without exact knowledge of how the atmosphere has changed. The Bailey Combustibles Analyzer provides the logical solution to the problem. In most applications it is sensitive to less than $\pm 0.2\%$ change in combustibles. It also assures uniform atmospheres and a uniform product.

In a commonly used Bailey control system, the Analyzer constantly samples the atmosphere gas. When per cent combustibles varies, a pneumatic signal from the recorder automatically controls the fuel rate to adjust the gas-air ratio and maintain the required amount of combustibles in the atmosphere.

A Bailey Oxygen Analyzer may be combined in the same case with the Combustibles Analyzer. Indicating and recording the per cent oxygen in heat treating atmospheres determines air leakage into the controlled atmosphere furnace. It may also be used as a further safety guide to indicate when a furnace has been purged effectively to permit the use of a hazardous blanketing gas.

Let a Bailey Engineer plan an analyzing and control system for you that will continuously safeguard the quality of your atmospheres and of your final product. Or, write to the Iron and Steel Division for Product Specification E65-3 with complete details on the Bailey Combustibles Analyzer. 59-1

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IRIDITE # 14 and # 14-2 (Al-Coat) for ALUMINUM

Two specially formulated finishes that give you maximum latitude in aluminum treatment. Both provide excellent corrosion protection and paint base. Iridite #14-2 is an improved product that allows greater flexibility in operation and coating thickness and produces the optimum in corrosion protection.
Either coating provides corrosion resistance superior even to complicated electrolytic treatments in a fraction of the time. These coatings also offer many other valuable characteristics: they have low electrical resistance, they aid in arc-welding, provide a good base for bonding compounds, have no effect on the dimensional stability of close-tolerance parts. Final appearances ranging from clear through yellow iridescence to full brown can be obtained. By dyeing, you can produce red, green, blue, orange or yellow finishes.

IRIDITE # 15 for MAGNESIUM

Produces a protective, paint base film with corrosion resistance at least equal to that obtained from long, high-temperature dichromate treatments in a fraction of the time and at room temperature. The appearance of the coating can be varied from light brown to dark brown and black.

APPROVED UNDER GOVERNMENT AND INDUSTRIAL SPECIFICATIONS

SEE FOR YOURSELF WHAT IRIDITE CAN DO . . . SEND SAMPLE PARTS FOR FREE PROCESSING. Look at the results, test the protection, evaluate the savings. Also write for handy Reference File of the most complete data published on chromate conversion coatings. Or, for immediate information, call your Allied Field Engineer. He's listed under "Plating Supplies" in your classified phone book.

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Manufacturers of Iridite Finishes for Corrosion Protection and Paint Systems on Non-Ferrous Metals; ARP Plating Chemicals.
West Coast Licensee—L. H. Butcher Co.

Personals . . .

Conrad F. Nagel, Jr., , vice-president of the Aluminum Co. of America, Pittsburgh, has retired after more than 41 years' service with Alcoa. A biographical appreciation of Mr. Nagel was published in the March 1956 issue of *Metal Progress*.

Reinhold Schempp and **S. A. Fronek** have been appointed managers of two of Crucible Steel Co. of America's larger plants. Mr. Schempp has been named manager of the Sanderson-Halcomb works, Syracuse, N. Y., while Mr. Fronek was chosen to head the Park Works, Pittsburgh. Affiliated with Crucible since 1927, Mr. Schempp had been assistant works manager of the Sanderson-Halcomb works since 1945 when the Sanderson and Halcomb plants were merged. Mr. Fronek, who has been with the Park Works since 1925, was assistant manager of the works for 12 years.

M. L. Greenlee , **A. A. Hatch** and **J. H. Luhan** have been added to the technical department of the metallurgical research division staff, Titanium Metals Corp. of America, Henderson, Nev. Mr. Greenlee is a 1956 graduate of the Colorado School of Mines with a bachelor's degree in metallurgical engineering. Before joining Titanium Metals, Mr. Hatch was a research metallurgist working on land gear applications at Menasco Mfg. Co., Burbank, Calif., and prior to that was associated with the Clevite Research Center, Cleveland. Mr. Luhan worked for the past two years as a research assistant at Case Institute of Technology, while studying for his master's degree.

Max C. Farmer has returned to the Beryllium Corp., Reading, Pa., to serve in the newly created position of technical director. Mr. Farmer was formerly general superintendent of the corporation, leaving in 1945 to work as director of the engineering division of the Allied Commission in Rome, Italy. In 1947, he was appointed assistant chief of the engineering division of Aluminum Co. of America, and more recently was staff metallurgist on the Materials Advisory Board of the National Academy of Sciences, Washington, D.C.

The New AUTOMET is on Display · Booth 278
Western Metal Exposition March 25-29
Pan Pacific Auditorium, Los Angeles

See the new Buehler Automet Polisher Attachment in operation.
Holds 6—1″ or 5—1¼″ specimen mounts for automatic mass production precision polishing.
The Automet attachment fits all present 8″ Buehler Low Speed Polishers.
Also on display will be the new Buehler Electro Polisher together with other Buehler equipment.
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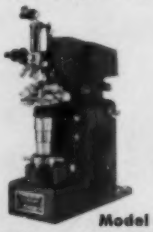
WILSON "TUKON" Micro Hardness Testers meet every fine test requirement. These precision instruments are invaluable in the proper testing of fine precision parts, fine wire, thin metal, shallow superficially hardened surfaces, jewels, plastics, glass, etc. WILSON "TUKON" testers operate with both Knoop and 136 degree Diamond Pyramid Indenters.

Model PB
Floor model for Micro Hardness Testing only. (Electrically operated)

Consult with WILSON Engineers on your hardness testing problem

Experienced WILSON Engineers will be glad to help you select the proper model for your particular requirement. This choice depends on the type and thickness of work to be tested, range of loads and other hardness testing equipment available.

Write for Booklet **DH-328** *on WILSON "TUKON" Micro Hardness Testers. Ask for* **DH-325** *on WILSON "ROCKWELL" Hardness Testers.*



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Personals . . .

Eugene A. March has been named assistant manager of the Crucible Steel Co. of America's Sanderson-Halcomb Works, Syracuse, N. Y., to succeed Reinhold Schempp. Associated with Crucible since 1946, he last held the post of chief metallurgist. **Robert K. Dunn**, staff metallurgist, will assume the post of chief metallurgist vacated by Mr. March.

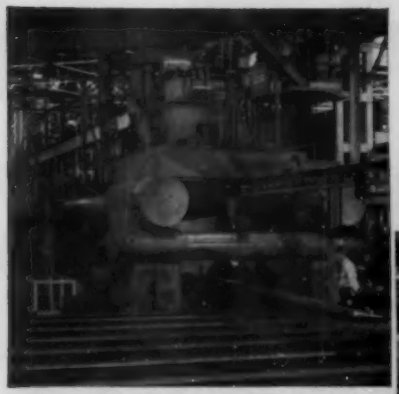
Arthur Herbener has become a member of the sales staff of the Electro Metallurgical Co., division of Union Carbide and Carbon Corp., Niagara Falls, N. Y. Mr. Herbener is assigned as a sales representative to the Pittsburgh district office. Before coming to Electromet, he was employed by Vanadium Corp. of America, Bethlehem Steel Co., General Electric Co. and Aluminum Co. of America.

S. C. Lawson is now midwest representative for the Wellman Bronze & Aluminum Co., Cleveland. With headquarters in Milwaukee, Wisc., Mr. Lawson's territory will cover the Chicago, Wisconsin and Minnesota areas. A manufacturers' representative since 1955, Mr. Lawson was formerly general sales manager of Ampco Metal Inc., Milwaukee.

George W. Stamm has been promoted to general manager of sales for Crucible Steel Co. of America, Pittsburgh. Coming to Crucible in 1940 as a sales trainee at the St. Louis Branch, Mr. Stamm acted as a toolsteel service engineer at the Syracuse, N.Y., plant, assistant manager and manager at the Cleveland sales branch, and assistant to the vice-president of sales. Until his promotion, he was assistant general manager in Pittsburgh.

Augustus B. Kinzel, vice-president in charge of research for Union Carbide & Carbon Corp., has been elected president of the American Institute of Mining, Metallurgical, and Petroleum Engineers, for one year beginning February 1958. Dr. Kinzel has been actively engaged in research work with Union Carbide and Carbon since 1926, when he joined the Electro Metallurgical Division as a research metallurgist.

For the King and Queen of Extrusion Presses . . . it's FIRTH STERLING HOT WORK DIE STEEL



Giant press extruding an aluminum spar section.

2500 lb. die blanks and a finished extrusion die of Firth Sterling HWD Hot Work Die Steel.

At Kaiser Aluminum & Chemical Corporation's Halethorpe Extrusion Works, operated under a U. S. Air Force lease, are two 8,000 ton capacity extrusion presses—the largest operating units designed and built in the United States. Presently extruding large, complex aluminum shapes—wing spars, wing panel sections, and missile hull sections, for the aircraft industry, the two giant presses, named Rex and Regina, utilize dies made from Firth Sterling Hot Work Die Steel.

Yes, Firth Sterling HWD is a monarch in its own right, with properties capable of withstanding the tremendous pressures of this king and queen of extrusion presses. This intricate process requires materials that can operate continuously in volume production without replacement. These giant presses each weigh 1500 tons and are capable of extruding aluminum shapes more than 85 feet long and over 1200 pounds each in weight. The use of Firth Sterling HWD is tangible evidence of the high opinion modern die makers have of the quality of the material.

HWD Steel is just one of the Firth Sterling line of more than 50 Tool and Die Steels. Ask for a Firth Sterling engineer to cooperate in your next die making problem to assure the correct grade and analysis.

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FOR NEW DEVELOPMENTS IN VACUUM METALLURGICAL EQUIPMENT LOOK TO—
Kinney
KINNEY high capacity pumping system shown at left.
This 500 lb. melting and casting furnace, remotely controlled from a graphic panel, can be readily converted to semi-continuous operation by addition of Vacuum locks.

"The outfit with the 'know how' has the answers" . . . and this is doubly true in Vacuum technology! KINNEY High Vacuum Pumps provided the answers "away back when" and you can practically chart the significant advances in Vacuum processing by the developments contributed to the art by KINNEY engineering.

The KINNEY oil sealed rotating plunger Pump, producing pressures down to 0.2 micron, continues to be the outstanding Pump of its kind in the world. The KINNEY Mechanical Booster Pump, introduced but four years ago, is contributing important advantages in securing clean, dry Vacuum at even lower pressures.

Now KINNEY offers the metallurgist new tools for production and research...complete High Vacuum Systems – Evaporators, Furnaces, Drying Ovens and Packaged Pumping Systems. And for the Metals industry – Complete High Vacuum Systems for Melting, Degassing, Casting, Refining and Heat Treatment.

Yes, "for new developments in Vacuum Metallurgical Equipment" get the answers – *based on experience* – from KINNEY.

WRITE: for Catalog No. 425, fully describing KINNEY High Vacuum Pumps, or for detailed information on your specific problem.

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3584C WASHINGTON STREET • BOSTON 30 • MASS.

Kindly send me catalog No. 425 ☐
Also send further information on your complete Vacuum equipment ☐

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Personals . . .

James K. McLaughlin has accepted a position as manager of sales, low frequency induction heaters, for Magnethermic Corp., Youngstown, Ohio. After graduating from Youngstown University in 1951, Mr. McLaughlin was employed by Magnethermic as a sales engineer and later served as design engineer.

Charles A. McFadden has been promoted to the post of manager, general industry division, Selas Corp. of America, Dresher, Pa. Mr. McFadden is concerned primarily with Selas automatic heating equipment as applied to metalworking operations. Coming to the firm in 1943 as a fuel engineer in the laboratory, he has held the positions of sales engineer and project engineer.

Charles J. Walton, assistant chief of the chemical division of the Aluminum Co. of America, Pittsburgh, Pa., was recently promoted to chief of the chemical division. Mr. Walton, who joined Alcoa's metallurgical division in 1931, was transferred to the chemical division in 1943, and three years later named assistant chief.

Robert K. Allen has been appointed superintendent of product development at the Alliance, Ohio, research center of the Babcock & Wilcox Co. Associated with B & W since his graduation from University of Colorado, School of Mechanical Engineering, in 1936, he was employed in an engineering capacity at the boiler division in New York and Pittsburgh until 1951 when he was made supervising engineer in New York. He last held the post of chief staff engineer.

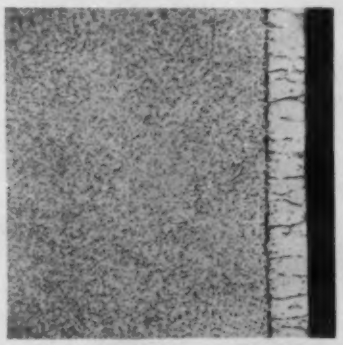
Andrew J. Frank has been assigned to the metallurgy division of the Denver Research Institute, Denver, Colo., as a research chemist working on problems concerning metals chemistry. Dr. Frank came to DRI from the Watertown Arsenal laboratories, Watertown, Mass., where he was chief of analytical research. He taught at Northeastern University in Boston and Tulane University, and was also affiliated with the Atomic Energy Commission Raw Materials Development Laboratory at the American Cyanamid Co. in Winchester, Mass., for two years.

How Chemical Coatings Protect Steel from Decarburization, Carburization, Scaling, or Nitriding

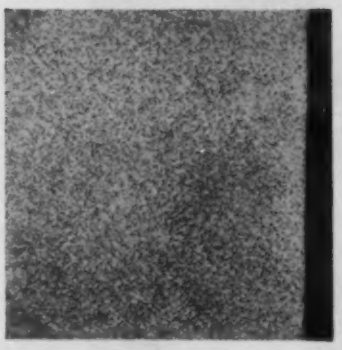
When steel is heated, it is often desirable to protect the surface from decarburization, carburization, scaling or nitriding. This is now possible with chemical coatings that are easily applied by dipping, brushing, or spraying. These protective coatings are suitable for selective carburizing or selective nitriding and also prevent decarburization or scaling.

For Prevention of Carburization or Decarburization

No-Carb prevents undesired carburization or decarburization when properly applied to clean and dry steel surfaces. It is used for selective carburization in solid or gas carburizing and for the prevention of decarburization on high alloy steels during heating for rolling, forging, and hardening. No-Carb is especially suitable for protecting the surfaces of high speed steel tools hardened from furnaces with or without atmospheric control. It is not designed for use in salt baths or on threaded areas.



Unprotected edge of high speed steel showing decarburization after hardening.



No-Carb protected edge of hardened high-speed steel. Note lack of decarburization.

For Selective Carburization in Liquid Baths and Solid Carburizers

No-Kase furnishes positive protection against carburization in pack carburizing compounds and in certain liquid carburizing salts. It also performs satisfactorily in some gas atmospheres. No-Kase is particularly advantageous where such difficult sections as threads are to be protected against carburization. In liquid carburizing, No-Kase is most effective in a barium energized salt bath composed of Park-Kase No. 1-S and replenished by Park-Kase No. 1 or No. 2 Energizer.

For the Prevention of Excessive Scaling on Steel

Here, Park No-Scale can be used effectively to prevent the formation of excessive scale on high alloy steels, die blocks and forgings. It acts as a die lubricant and prevents the loss of valuable alloys during heating operations. No-Scale is also used on the outside of steel pots to prevent excessive oxidation.

Example of selective carburization with Park No-Kase. Note clear cut line of demarcation between the protected and unprotected areas.

Carbon Preventive

Carbon Preventer is a plastic compound for the prevention of carbon penetration into steel. It is used on threaded sections and other locations where the removal of No-Carb might be difficult. It is not designed for use in salt baths. For further information or an analysis of your specific problem, write to PARK CHEMICAL COMPANY, 8074 Military Avenue, Detroit 4, Mich.

Continuous CIRC-AIR Tempering

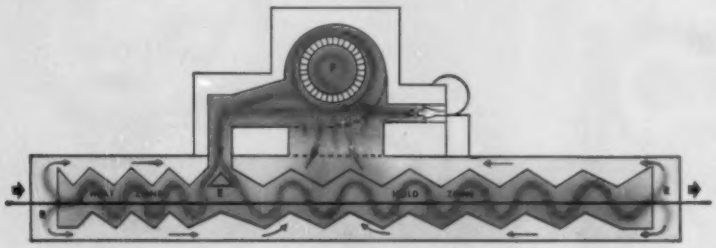
AT ± 5° F.

Industrial's "Circ-Air" tempering furnace is the most efficient heating machine ever designed.

The turbulent recirculation of hot gases through and around the work insures maximum and uniform heat transfer. Proper channeling of the hot gases to the work prevents wasteful dissipation of heat; and puts heat where it is needed — on the work.

A "Circ-Air" processing 2000 lbs. per hour at 1300° F., holding ±5° F., forces 14,500 C. F. M. of hot gases through the work. "Circ-Air" heating is recirculation at its best.

The continuous "Circ-Air" is suitable for heating steel, brass, aluminum and cast iron at temperatures up to 1450° F.



WHY THE CIRC-AIR IS THE BEST TEMPERING FURNACE!

The work is carried on a continuous conveyor. Loading can vary; ¼" bolts are densely loaded up to 3" deep. Less dense loading may be 20" deep. A 3' x 21' "Circ-Air" tempers over 2000 lbs. per hour.

Hot gases from the combustion chamber "C" and recirculated gases returning from the work chamber mix in the fan area "F." Entering the heating area through "T" at control temperature, balanced heat is directed to the charge and discharge ends, and is returned to the mixing chamber. The continuous V construction of the metal liner forces the hot gases up and down through the load at high velocity. The hot gases in the heating zone flow counter to the work. Heat transfer is rapid. Equilibrium is reached at point "E", and ±5° F. is held the length of the holding zone. Heating is without temperature head.

"Circ-Air" furnaces have been built in widths up to 108 inches, in lengths up to 165 feet, for temperatures from 250 to 1450° F., and capacities from 200 to 16,000 lbs. per hour. *Send for Bulletin 13-A*

INDUSTRIAL
HEATING EQUIPMENT CO.

CIRC-AIR 3570 FREMONT PLACE, DETROIT 7, MICHIGAN • WALNUT 3-7000

PIONEERS AND STILL LEADERS IN RECIRCULATION

Personals . . .

A. I. Nussbaum, formerly sales manager of Stanat Mfg. Co., is now in charge of the rolling mill division of Loma Machine Mfg. Co. Inc., New York.

John W. Porter, assistant vice-president of American Steel Foundries, Chicago, has retired after more than 41 years with the firm. Graduating from the University of Kentucky, Mr. Porter was employed at the company's East St. Louis, Ill., works as a chemist. He later served as assistant works manager of the Chester, Pa., and Granite City, Ill., plants, works manager of the East Chicago, Ind., plant and manager of operations of the cast armor division. At retirement, he was working at the manufacturing research laboratory in East Chicago.

William Rostoker has been promoted to assistant manager of the metals research department at Armour Research Foundation of Illinois Institute of Technology. He will be in charge of the applied metallurgy, foundry and steelmaking, physical metallurgy, and welding sections. Dr. Rostoker, who previously served as senior metallurgist and supervisor of physical metallurgy, joined the Foundation in 1951, and before that taught at Illinois Institute of Technology and the University of Birmingham in England.

Frederick W. Rys has been given a new assignment in the engineering and construction division of Koppers Co., Inc., as vice-president and manager of the Freyn Dept. Mr. Rys was assistant manager of the Freyn Dept. until last year when he was named vice-president and manager of construction projects for Koppers International, C. A., a wholly owned subsidiary of Koppers handling the company's foreign activities.

J. A. Cairns has been elected to the board of directors of Allied Research Products, Inc., Baltimore, manufacturer of chromate conversion coatings and plating chemicals. Mr. Cairns has been associated with the organization since 1948 and in 1955 was named sales manager of the marketing subsidiary, Allied Research Sales Corp.

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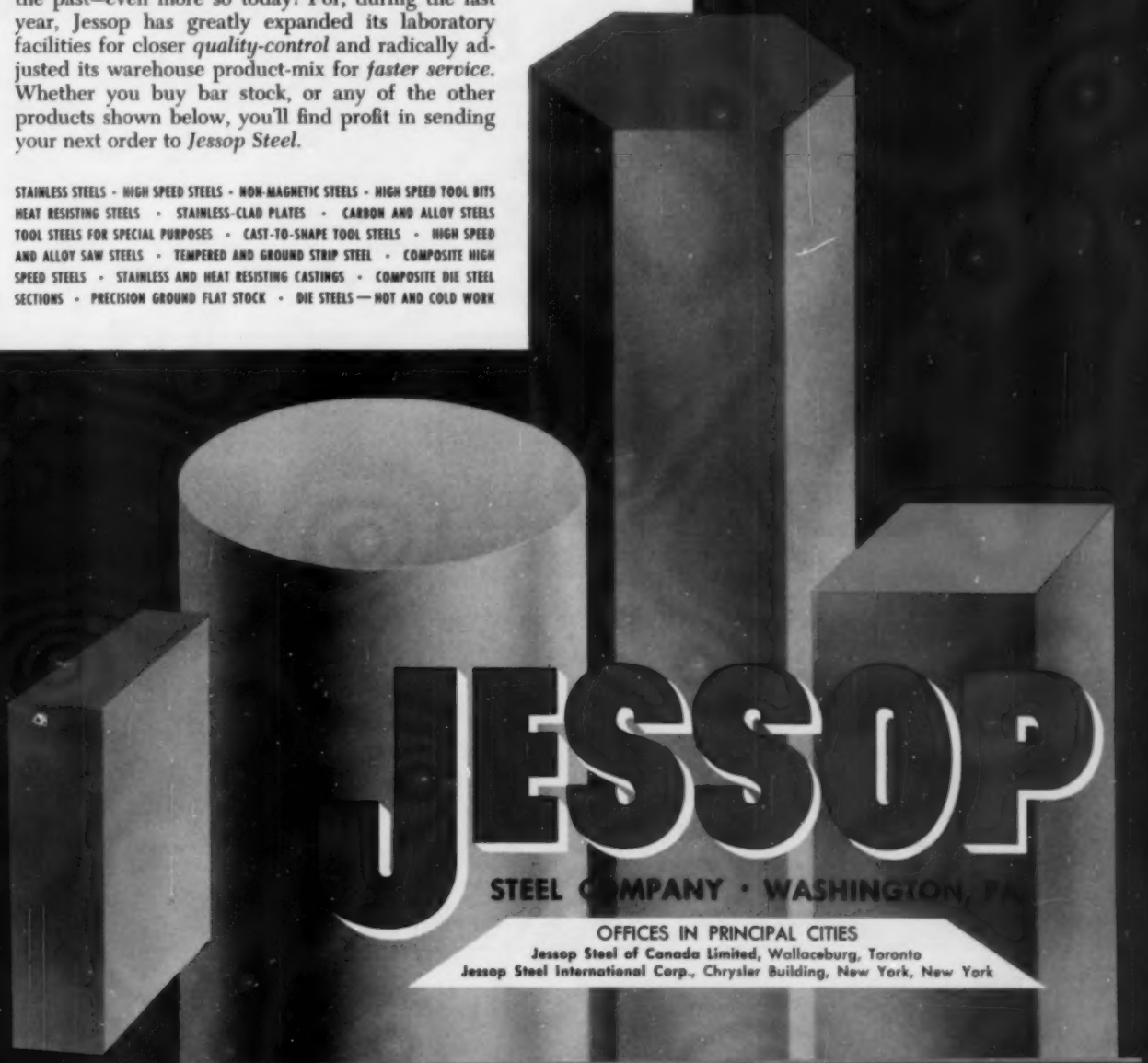
HIGH QUALITY*

GOOD SERVICE*

* *High quality* and *good service* are apt words to describe what you get when you buy tool and high-speed bar stock from *Jessop Steel.* Descriptive in the past—even more so today! For, during the last year, Jessop has greatly expanded its laboratory facilities for closer *quality-control* and radically adjusted its warehouse product-mix for *faster service.* Whether you buy bar stock, or any of the other products shown below, you'll find profit in sending your next order to *Jessop Steel.*

STAINLESS STEELS · HIGH SPEED STEELS · NON-MAGNETIC STEELS · HIGH SPEED TOOL BITS · HEAT RESISTING STEELS · STAINLESS-CLAD PLATES · CARBON AND ALLOY STEELS · TOOL STEELS FOR SPECIAL PURPOSES · CAST-TO-SHAPE TOOL STEELS · HIGH SPEED AND ALLOY SAW STEELS · TEMPERED AND GROUND STRIP STEEL · COMPOSITE HIGH SPEED STEELS · STAINLESS AND HEAT RESISTING CASTINGS · COMPOSITE DIE STEEL SECTIONS · PRECISION GROUND FLAT STOCK · DIE STEELS—HOT AND COLD WORK



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U.S.I. CHEMICAL NEWS

A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries

Greenleaf to Handle Market Development of Zirconium And Titanium for U.S.I.

William C. Greenleaf has been named Manager of Metals Development for U.S.I. and will be responsible for market development and sales of zirconium and titanium sponge, to be produced from U.S.I.'s two new plants now being built in Ashtabula, Ohio.

A recognized authority in the field of zirconium and titanium, Mr. Greenleaf presented three papers during the 1955 Atomic Industrial Forum Zirconium Program, describing (1) melting of zirconium, (2) fabrication of zirconium, and (3) zirconium mill products and prices. He also conceived and developed processes now in general use for producing both wide-sheet and flat-bar titanium and zirconium by continuous strip-mill techniques.

Faye Named Manager of Sodium Product Sales

Martin Faye has been named Manager of Sodium Product Sales for U.S.I. and will be responsible for coordinating sales and sales promotional activities for metallic sodium, "U.S.I. Isosebacic" acid and related products.

Mr. Faye joined the U.S.I.-National Distillers organization in 1952 in the Market Research and Development Department.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing the Editor, U.S.I. Chemical News.

A zirconium-copper alloy now available is reported to combine high electrical conductivity with good strength retention at elevated temperatures. Suggested for electrical motor commutators serving above 500°F where strength is needed. Conductivity is 95.8% of copper. **No.1193**

Titanium wire cloth is now on the market in sizes from 60 mesh to coarser grades. It is reported to be particularly suitable for filtering or screening highly corrosive materials. **No. 1197**

Zirconium and Titanium Lick Roughest Corrosion Problems

Metals to be Available at Lower Cost in Future; Provide Long-Lived Materials of Construction; Complement Each Other on Corrosion Resistance

It is now practical to fabricate equipment which is *corrosion-resistant to almost every substance encountered in industry*, by using either zirconium or titanium metal. Alloys of either metal, or possibly both, may extend the range even further.

Industrial applications of these metals have been hampered by two considerations: availability and price. Zirconium will shortly be produced at a rate sufficient to supply industrial needs, and titanium has been available to industry during the past two years. And it is expected that increased production of these metals during the next few years will result in significant price decreases.

Twelve to thirteen thousand tons of titanium were available in 1956 and present construction schedules indicate that the figure will rise substantially in 1957. U.S.I.'s new plant alone will add 5,000 tons to the annual production capacity by the end of the year. Zirconium will be on the market in quantity by mid-1957. When its new plant at Ashtabula, Ohio gets under way, U.S.I. will be able to supply 500,000 pounds or more per year to commercial users in addition to its Atomic Energy Commission commitments of 1,000,000 pounds per year.

New Metals Economical

Chemical process equipment can now be fabricated from titanium for a little over twice the price of stainless steel, and it is expected that in the future titanium equipment will be only 50-75% higher than stainless. Commercial grade zirconium equipment will probably be priced only 75-100% higher than stainless when volume production is reached.

Typical Corrosion Resistances* of Zirconium and Titanium

Corrosive Media	Metal Resistance	
	Zirconium	Titanium
Sulfuric Acid	excellent to good below 80%	good below 5%
Nitric Acid	excellent	excellent
Hydrochloric Acid	excellent	good below 10%
Phosphoric Acid	excellent to fair below 85%	poor
Chromic Acid	excellent	excellent to good
Aqua Regia	poor	excellent
Wet Chlorine Gas	poor	excellent
Chlorine Water	excellent	excellent
Sodium Hydroxide	good below 90%	good below 50%
Ferric Chloride	poor	excellent
Calcium Chloride	excellent	excellent
Cupric Chloride	poor	excellent
Sodium Chloride	excellent	excellent
Ammonium Chloride	excellent	excellent
Aluminum Chloride	excellent	excellent to fair

*Above data do not cover all conditions because of space limitations. Literature references may be obtained by writing the Editor, U.S.I. Chemical News, 99 Park Ave., N. Y. 16, N. Y.

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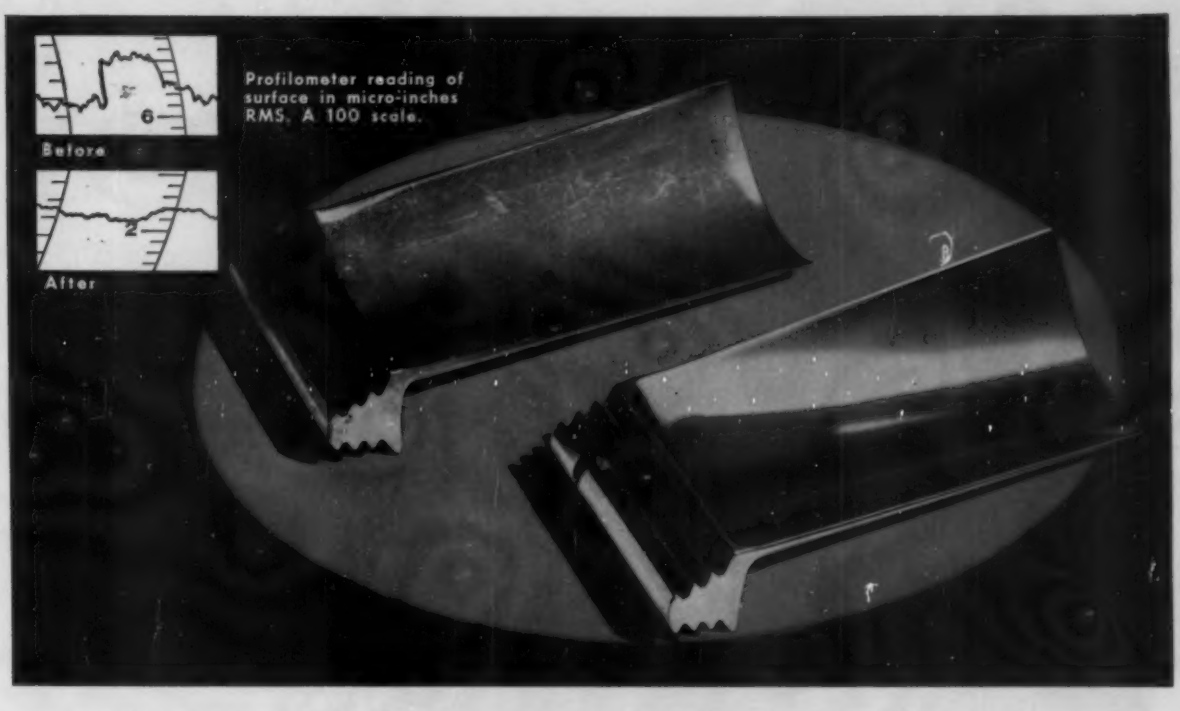

Cut parts finishing costs, maintain exact tolerances, get absolute uniformity with *Roto-Finish* processes

Roto-Finish, pioneers in precision barrel finishing, offer you a complete finishing service. Savings on deburring, descaling, grinding, polishing, coloring and surface improvement are tremendous. Expensive hand finishing methods can be eliminated.

Roto-Finish processes are controlled to produce the finish you need with no significant dimensional changes. You get absolute uniformity of finish in quantity lots.

Many prominent manufacturers now using Roto-Finish processes are saving money on finishing costs. (Names on request).

ROTO-FINISH CHIPS, COMPOUNDS AND MACHINES ARE OF THE HIGHEST QUALITY

Roto-Finish has never sacrificed quality for the sake of price. Through the years, Roto-Finish has carried on a continuous program of process and product improvement to meet the needs of modern industry. When you choose Roto-Finish processes, you can be sure that you are getting the best in supplies, equipment and complete continuing engineering service.

ROTO-FINISH GUARANTEES RESULTS

There is no costly trial and error involved in the purchase of Roto-Finish equipment. You submit unfinished parts to Roto-Finish along with a finished sample and a description of the finish you require. These sample parts are processed in the Roto-Finish Sample Processing Laboratories, where experienced engineers determine the combination of chips, compounds, and machine required to do the job. Roto-Finish guarantees to reproduce the same results in your plant, using the Roto-Finish processes, that are achieved in sample processing. This service demonstrates for you exactly what you can gain by using Roto-Finish processes.

The sample processing service is available to help you with your finishing problem. Take advantage of this opportunity to save on finishing costs. Send samples of finished and unfinished parts and details of the type of finishing equipment available in your plant.

SEND FOR THIS FREE TECHNICAL DATA FOLDER

It describes the basic process, chips and compounds and the complete Roto-Finish line of standard and special machines.

Roto-Finish COMPANY

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Phone: FI 3-5578

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ENGLAND — Roto - Finish Limited — Mark Road, Hemel Hempstead — Hertfordshire
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SPECIFIED ON BLAKESLEE WASHER

Automatic Parts Washer
manufactured by G. S.
Blakeslee & Co., Chicago, Illinois

for automated metal cleaning!

• Degreasing aluminum parts is a production operation in this midwestern plant — a large manufacturer of aircraft components. This Blakeslee Parts Washer provides a fast, continuous method for quickly dissolving grease and lubricants, delivering clean, dry parts ready for assembly and finishing. Solvent is heated to 212 F by two sets of coils, fired by special Eclipse combustion assemblies at each end of the washer. Maximum efficiency and dependability are achieved because burners, injectors, pilots, blowers, air gas mixers, control valves, and Zero gas governors — the complete combustion assemblies — were engineered and manufactured under the co-ordinated control of *one maker*. If you are a manufacturer or a user of heating equipment, such as furnaces, ovens, kilns, driers, etc., you can get a broader selection of combustion equipment from Eclipse's complete line. Write for Bulletin H.

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1127 Buchanan St., Rockford, Illinois
Eclipse Fuel Engineering Co. of Canada, Ltd., Don Mills, Ontario

Eclipse COMBUSTION EQUIPMENT
"Most complete line, anywhere"

Personals . . .

Tadeusz Sendzimir was elected to the board of directors of the Waterbury Farrel Foundry & Machine Co., Waterbury, Conn., at its December meeting. Waterbury Farrell recently acquired the Sendzimir cold strip mill of the Armzen Co., Waterbury, Conn., to be known as the Sendzimir Mill Div. with Mr. Sendzimir as manager. Mr. Sendzimir is also owner and director of the Sendzimir Co., including Sendzimir Procedes, Paris, and Sendzimir, Ltd., London.

E. B. Whittemore, formerly a member of the sales department, is now assistant general manager of sales, Cold Metal Products Co., Youngstown, Ohio.

H. H. Brandt has assumed a new position as New York district representative for Laclede-Christy Div., H. K. Porter Co., Inc., St. Louis, Mo. Previously, he was employed by National Carbon Co. and Bethlehem Steel Corp.

E. S. Machlin will serve as general editor for a new service to be provided for the metal industry by Technical Digest Service, Inc., New York. The service will publish monthly digests and digest translations of current articles on production, design, development and research.

W. Paul Eddy, chief of engineering operations at the Pratt & Whitney Aircraft Div., United Aircraft Corp., Hartford, Conn., was elected president of the Society of Automotive Engineers for 1957. Mr. Eddy joined Pratt & Whitney in 1944 after 15 years with General Motors Corp., and has held his present position since 1946.

R. David Thomas, Jr., has been named president of the Arcos Corp., Philadelphia, Pa. Until his promotion, Mr. Thomas was executive vice-president of the company.

William J. Goodwin, until recently with the research and development division of Electro Metallurgical Co., a division of Union Carbide and Carbon Corp., Niagara Falls, N. Y., is now a reasearch engineer in the crucible laboratory of Electro Refractories & Abrasives Corp., Buffalo, N. Y.

Simple Arithmetic...
Type 302, Sheet Base Price 50.00 cents per lb.
Type 430, Sheet Base Price - 39.25 cents per lb.
Saving 10.75 cents per lb.
in Stainless SHEET Costs!

Now you can SAVE $215 per ton in base price alone!

Many designers and fabricators who are currently using Type 302 stainless can, in numerous applications, specify Type 430 straight chromium stainless and take advantage of the 10¾ cents per pound difference in base price. Some of our customers are already saving more than $215 per ton using our 430 MicroRold stainless sheet.

The steel industry estimates that 50% of all stainless sheet applications could satisfactorily employ Type 430, the least expensive of all stainless grades, as an economical and practical material. When properly applied, Type 430 has all the desirable qualities of beauty, corrosion resistance, strength, long life and low maintenance that no other material, except stainless, can offer.

We are currently producing our MicroRold Type 430 sheets up to 48" wide in thicknesses .005" to .109" with 2B or 2D finishes; and in thicknesses .010" to .109" in No. 3, 4 and 7 finishes.

Send for Your copy, "Care and Use of 430 MicroRold Stainless Steel"

Washington Steel *Corporation*

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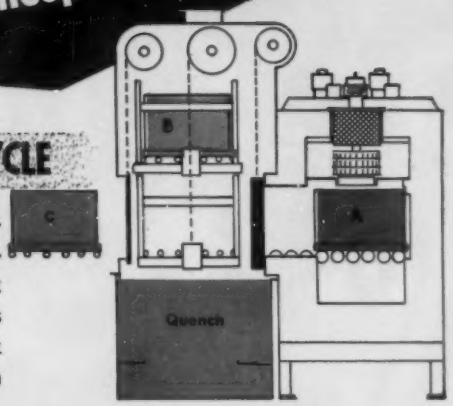
Sealed Cycle.....

A Dow Furnace FIRST for Batch-type controlled atmosphere furnaces.

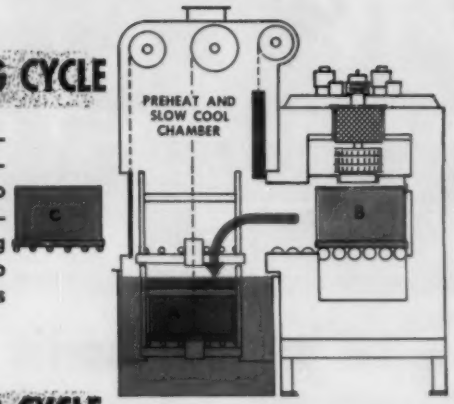
Step 1—LOADING CYCLE

Box A containing full furnace load of parts processing in work chamber. Box B—fully loaded, pre-heats in the upper vestibule. Box C—fully-loaded, waits on conveyor.



Step 2—QUENCHING CYCLE

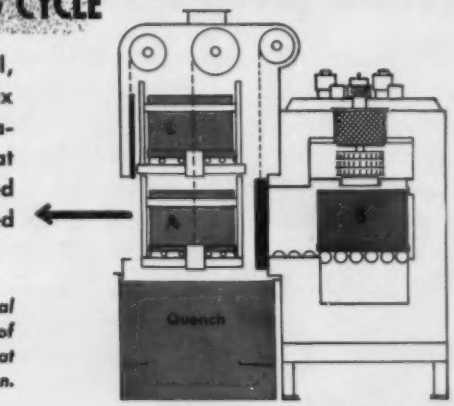
Box A completely processed, moves out to elevator and is lowered into quench; bringing pre-heated Box B to loading level. Box B is pushed into heat chamber and door is closed.



Step 3—RELOADING CYCLE

After proper interval, outer door is opened. Box C is placed on upper elevator and raised to pre-heat position as Box A is lifted from quench and removed from lower elevator.

Sealed Cycles' double door seal affords complete flexibility of processing without exposing heat chamber to air contamination.



Upper vestibule is easily adapted for slow cooling. Quench is adaptible for interrupted quenching.

DOW FURNACE COMPANY

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Phone: KEnwood 2-9100

First WITH MECHANIZED, BATCH-TYPE, CONTROLLED ATMOSPHERE FURNACES

Personals . . .

James L. Scot, formerly affiliated with the University of Tennessee, is now a member of the staff of the Oak Ridge National Laboratory, Oak Ridge, Tenn.

Leslie L. Seigle has assumed new duties as manager of metallurgy research at the Stet Research Laboratories, Sylvania Electric Products Inc., Bayside, N. Y. Dr. Seigle joined Sylvania in 1951 as an engineering specialist, and more recently directed the Research Laboratories' basic metallurgy programs as well as coordinating non-nuclear metallurgy research. In addition, he also serves as an adjunct professor of metallurgy at New York University.

Clyde R. St. John is now general staff metallurgist for Kaiser Aluminum & Chemical Corp., Oakland, Calif. Joining Kaiser Aluminum in 1946 at the Trentwood, Wash. works, he later moved to the Newark, Ohio, plant where he served as assistant chief metallurgist, superintendent of inspection, assistant plant superintendent and plant superintendent. In 1955 he returned to Trentwood as mill products manager.

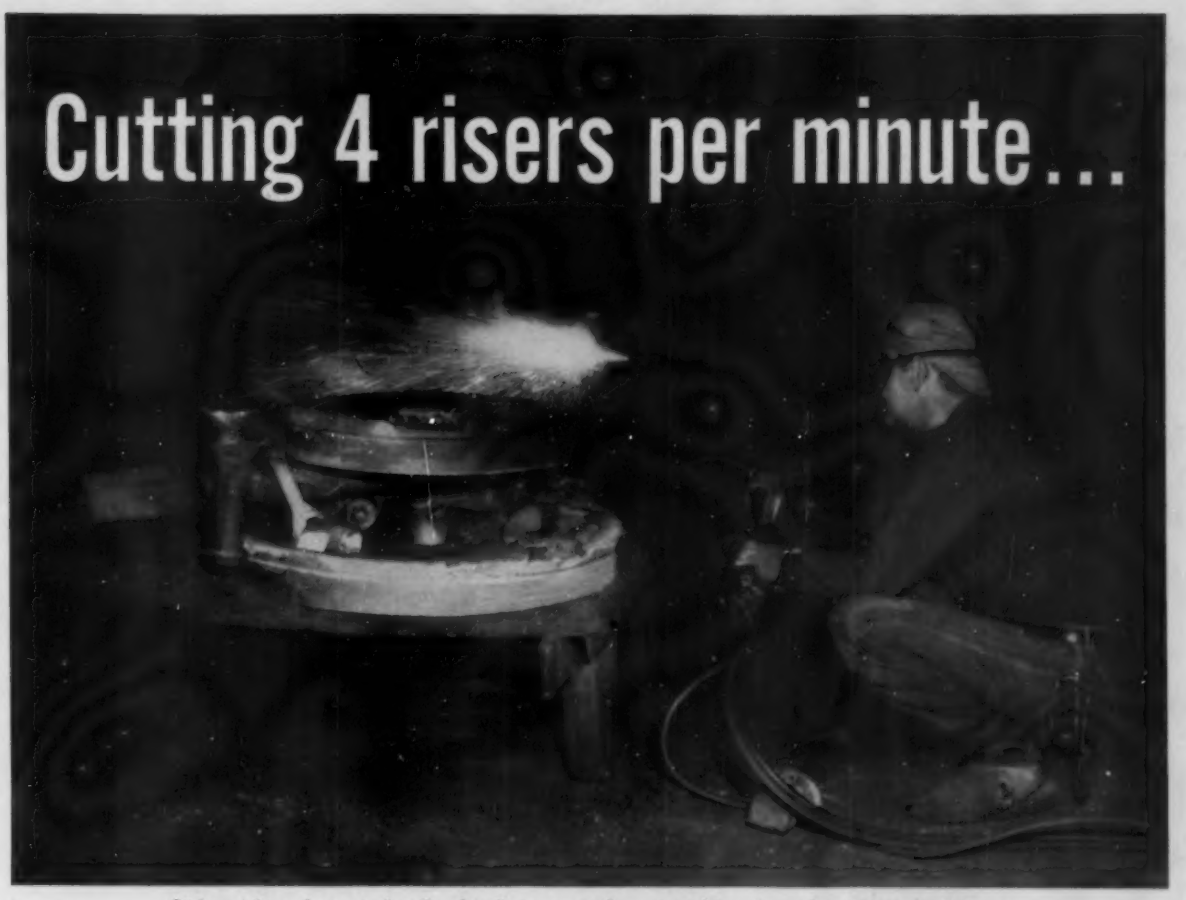
K. W. Thompson, president of the K. W. Thompson Tool Co., New Hyde Park, L. I., N. Y., was elected president of the Investment Castings Institute at the Institute's fourth annual meeting in Detroit last fall. The new treasurer of the Institute is **V. S. Lazzara**, president of Castings Engineers, Inc., Chicago.

Gary W. Wilson has been appointed sales representative for the American Brass Co., Waterbury, Conn., and will be responsible for the Reading-Allentown-Easton, Pa., area. Mr. Wilson received the company's two-year mill training course and recently served as a sales correspondent in the Philadelphia office.

Ford E. Dreves is now district manager of the Philadelphia territory, Wyckoff Steel Co., Pittsburgh. Mr. Dreves will make his headquarters at Philadelphia.

Phillip L. Rittenhouse, formerly a student at the University of Tennessee, has been added to the staff of the Oak Ridge National Laboratory, Oak Ridge, Tenn.

Cutting 4 risers per minute...



Lightweight and easy to handle, this OXWELD powder-cutting blowpipe makes fast work of risers.

Powder-Cutting speeds removal operations 300%

Removing risers from stainless steel castings need no longer be costly and time consuming. Pictured above is a typical powder-cutting operation at the Ohio Steel Foundry Company, Springfield, Ohio. Here, 2 by 4 inch thick stainless steel risers are removed by powder-cutting in only 15 seconds. By methods previously used, this operation took up to four times longer.

In the powder-cutting process metal powder is automatically injected into an oxygen flame to increase the flame's heat and severing action speed. The powder process is helping users gain new efficiency and speed in the removal of gates and risers, sand incrustations, and casting defects.

The powder-cutting blowpipe used in this operation, an OXWELD AC-4, is designed for hand cutting of oxidation resistant metals such as stainless steel, chrome alloys, and cast iron. Heavier apparatus is also available for manual and mechanized operations.

Increase your production and profit—call your local LINDE representative, or write for illustrated literature on LINDE's modern processes. Start saving now, do it today.

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uses parts anything
—like these . . .

we'll show you
how to—

reduce
your
costs!

Through Albion's modern *resin shell* casting techniques, pearlitic and ferritic malleable irons may be cast to your specifications and tolerances with physical properties to suit your specific range of applications.

And more important, Albion's *resin shell molded* pearlitic and ferritic malleable iron castings combine the advantages of both castings and forgings. They're produced to extremely close dimensions to eliminate excess metal as well as machining or grinding operations; for greater production time, tool and labor savings.

Phone your Albion Malleable Iron Company representative today. He can show you how to save valuable time and dollars through Albion's modern casting techniques.

Albion's Research and Development Laboratory facilities are at your disposal. Whether you are designing new or reviewing present parts, Albion's engineers are anxious to assist you.

ALBION MALLEABLE IRON CO. ALBION MICHIGAN

Personals . . .

Henry H. Hausner and **Marcel A. Cordovi**, adjunct professors at the Polytechnic Institute of Brooklyn, are teaching the first course in the East on the metallurgy of nuclear power reactor materials. Until now, courses of this type have been given only in national laboratories, such as Oak Ridge, and have not been available in the general college curricula. Dr. Hausner is general manager of the nuclear engineering division of the Penn-Texas Corp., New York, and Mr. Cordovi heads the materials and testing department of the atomic energy division, Babcock and Wilcox Co., New York. Both are working on contracts for the U.S. Atomic Energy Commission.

S. S. Rice has accepted a position as chief metallurgist of J. Bishop & Co., Malvern, Pa. Mr. Rice was chief metallurgist of the Autoyre Co. division of Ekco Products Co., Oakville, Conn., until the plant recently closed down.

Robert F. Mehl, director of the Metals Research Laboratory of Carnegie Institute of Technology, is the recipient of the 1956 Pittsburgh Award of the Pittsburgh Section of the American Chemical Society for outstanding service to chemistry. This award is presented "in recognition of work worthy of note toward increasing chemical knowledge, promoting industry, benefiting humanity or advancing the Pittsburgh Section."

C. S. Mushinski now holds the newly created position of superintendent, bar products, at the Park Works of Crucible Steel Co. of America, Pittsburgh. In this new post, Mr. Mushinski will continue to be responsible for the annealing, heat treating and bar finishing departments, which he formerly managed as superintendent. Associated with Crucible for 33 years, Mr. Mushinski has been with the Park Works since 1931, and has held his last position since 1938.

Arthur R. Tobias was recently appointed engineer in charge of the mechanical test room of the Garlock Packing Co., Palmyra, N.Y. Since joining the company in 1951, he has served as a machine design engineer and supervisor in charge of the mechanical seal test room.

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Kodak Industrial X-ray Film, Type AA, gives you greatly increased speed — a film characteristic that brings the radiographer greatly extended possibilities.

As an example: by using reduced kilovoltage and usual exposure time, greater radiographic contrast and easier readability are obtained.

In addition to ranging up to double the speed, this new film retains the fine sensitivity characteristics which made Kodak Type A the most widely used x-ray film in industry.

Kodak Industrial X-ray Film, Type AA, can save you time and extend the usefulness of your present radiographic equipment. Get all the details. Contact your x-ray dealer or Kodak Technical Representative.

EASTMAN KODAK COMPANY, X-ray Division
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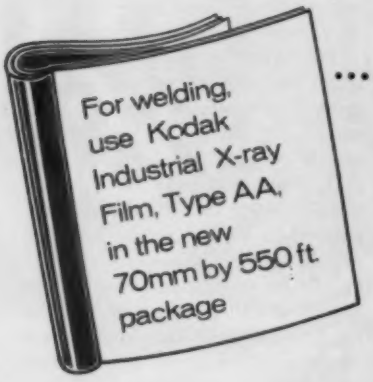


Read what the new Kodak Industrial X-ray Film, Type AA, does for you:

- Reduces exposure time—speeds up routine examinations.
- Provides increased radiographic sensitivity through higher densities with established exposure and processing technics.
- Gives greater subject contrast, more detail and easier readability when established exposure times are used with reduced kilovoltage.
- Shortens processing cycle with existing exposure technics.
- Reduces the possibility of pressure desensitization under the usual shop conditions of use.

Kodak
TRADE MARK

Digests of Important Articles

Hot Compacted Copper Powder

Digest of "The Porosity and Permeability of Hot-Compacted Copper Powder", by G. Arthur, *Journal* of the Institute of Metals, Vol. 84, May 1956, p. 327-332.

IN A PREVIOUS PAPER "Porosity and Permeability Changes During the Sintering of Copper" (reviewed in *Metal Progress*, September 1955), G. Arthur described the results of his experiments on the porosity and permeability of cold compacted and sintered copper specimens. The present paper is an extension of the previous studies to include hot pressed powder specimens. Three different size ranges of powder were used and compacting was done at 1300, 1475 and 1650° F. The main variable in the study was the compacting pressure, ranging from 0 to 1200 psi.

As expected, the permeability decreases with increasing compacting pressure, and at any one pressure the permeability decreases with increasing temperature. A more interesting result from the fundamental point of view is the fact that for a given powder a relationship exists between permeability and interconnected porosity, and this relationship is independent of the compacting temperature within the range investigated (1300 to 1650° F.). A comparison is made between the hot pressing technique and either the loose powder method or the cold pressing and sintering techniques. It is shown that for a given total porosity the permeability of the hot compacted material is intermediate between the value for cold compacted and the value for loose-sintered materials, the loose powder material having the highest permeability.

It would be dangerous to conclude from these results that the loose powder technique is the best method for manufacturing porous metals.

It must be borne in mind that in many applications of porous metals, such as for boundary layer control or sweat cooling, strength is a most important factor. For such applications, the designer does not care much about porosity, but wants maximum permeability combined with maximum strength. It is hoped that in future studies the author will include measurements of tensile strength and elongation.

In the last portion of the article, some of the experimental results are interpreted in terms of the various theories of sintering. The discussion presented is rather confusing and since the author himself does not draw any definite conclusions, it is probably because he felt (and so does the reviewer) that the experiments he performed did not lend themselves to a clear theoretical interpretation.

POL DUWEZ

Sprayed Metal Coatings

Digest of "Developments in Sprayed Metal Coatings", *Corrosion Technology*, Vol. 3, October 1956, p. 321-322.

SPRAYED METAL COATINGS, used for over 25 years for repair and maintenance work, are now being used in manufacturing. Molybdenum-base alloys, applied by spraying, bond readily to the base metal and make a most excellent journal material for bearings.

Formerly the spray gun operated with metal powder or wire fused by an oxygen-gas flame, the liquid particles being blown by compressed air against the article to be coated. With metal powder the speed was slow and much of the powder was wasted. Now metal powder can be applied using oxygen rather than compressed air. A central oxygen jet propels the powder out of the nozzle into the spray stream where it is surrounded by the burning fuel (acetylene or hydrogen). This gives over 90% deposit efficiency with such materials as hard nickel-base alloys and ceramic materials such as alumina and zirconia.

New self-fluxing sprayed powder coatings have a nickel base. The fluxing elements contain boron and silicon. Slight oxidation of the powder produces a borosilicate flux. Such coatings range in hardness from Rockwell C-30 to C-65. They exhibit excellent resistance to corrosion, oxidation, abrasion and wear, and have a very low coefficient of friction. These alloys usually fuse after spraying.

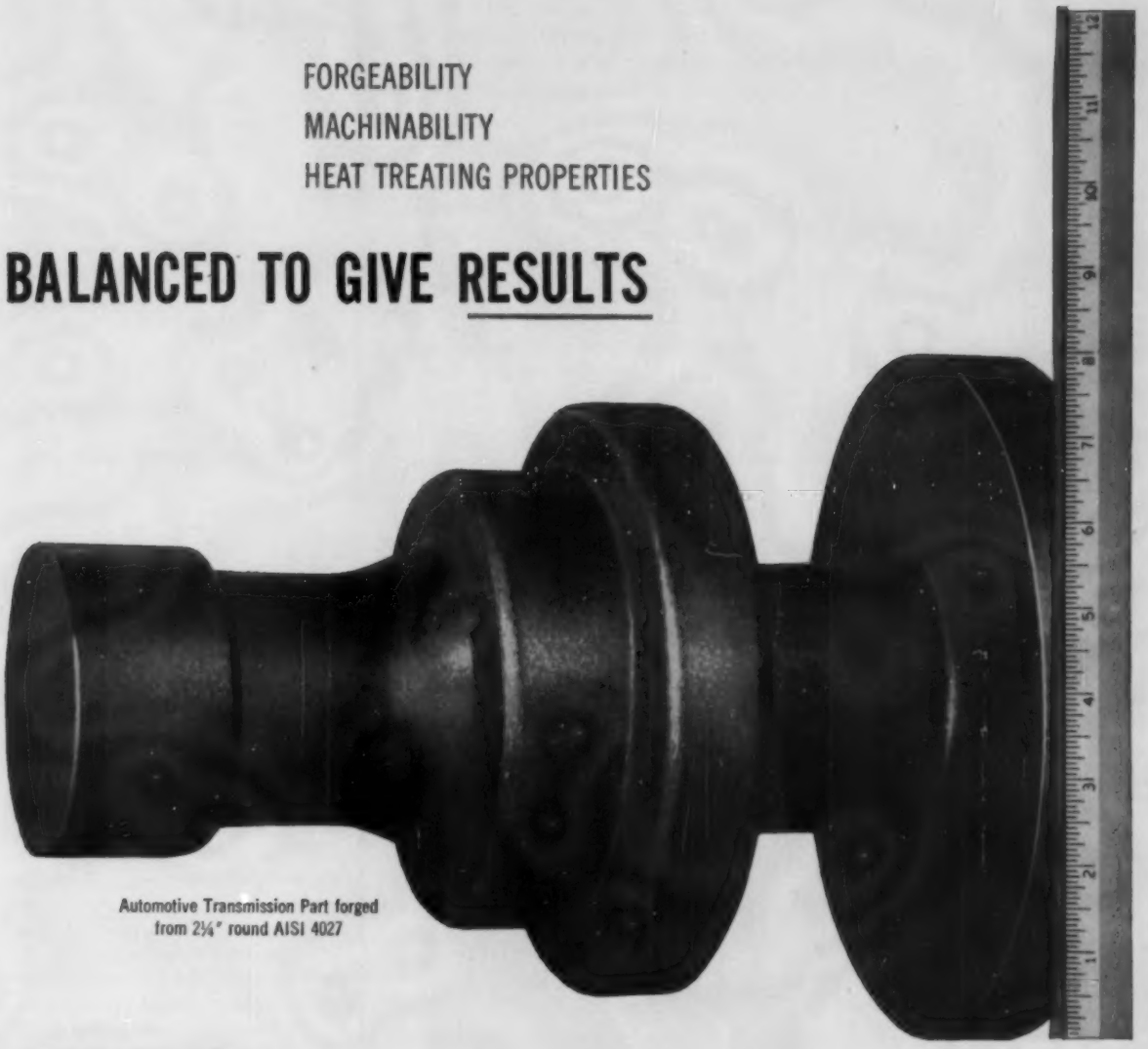
Other alloys have been developed for use without fusing after deposit. They are designed to resist the formation of oxides without the addition of self-fluxing agents. They include high-chromium steel and chromium-nickel alloys.

Until recently, ZrO_2 and Al_2O_3 have been difficult to spray because of high melting point and low heat conductivity, but with the new process, coatings of these materials 0.005 to 0.025 in. thick, resistant to high-temperature abrasion and thermal shock, can be applied effectively.

The article includes data which show only the properties of the sprayed ceramics, alumina and zirconia. The Al_2O_3-base coatings are said to be harder and stronger than ZrO_2; their coefficient of expansion is 4.3×10^{-6} per °F., thermal conductivity is 19 Btu. per hr. per sq.ft. per in. per °F. (compared with 185 to 320 for steels), and they can be deposited 0.01 in. thick at 15 sq.ft. per hr. The ZrO_2-base coatings are heavier and more refractory; their coefficient of expansion is 6.4 ×

FORGEABILITY
MACHINABILITY
HEAT TREATING PROPERTIES

BALANCED TO GIVE RESULTS



Automotive Transmission Part forged
from 2¼" round AISI 4027

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Forging Quality Steel Bars

For high-quality forgings at low production costs you need forging steels with the right balance of machinability, forgeability and heat treating properties in carbon and alloy grades.

At Jones & Laughlin, strict metallurgical control of every process from ore mine to finishing mill assures the correct balance of these essentials for high-quality forgings.

J&L's staff of experienced metallurgists is available to analyze your particular requirements.

J&L FORGING STEELS—EXACTLY TO SPECIFICATION

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STEEL CORPORATION · PITTSBURGH

A lightweight skin section 5 feet by 3 feet in compound contours. One side an airfoil, the other side a heat collection grid of maximum conductivity through the skin. A tolerance of .010" on mating surfaces.

This casting was produced by a unique foundry technique developed by the aluminum foundry of Morris Bean & Co. A rush schedule was met on prototypes, and the casting is now delivered in production quantities.

If you seek new approaches on difficult-to-form access doors, fins, airfoil sections, leading edges, or other problem shapes, you should become acquainted with—

Morris Bean & Company
Yellow Springs 5, Ohio

a cast aircraft skin?

see this casting and others at Booth 756 at the Western Metals Show

BEAN

Sprayed Metal . . .

10^{-6} per °F., thermal conductivity is 8 Btu. per hr. per sq.ft. per in. per °F., and they can be deposited 0.01 in. thick at 10 sq.ft. per hr. The porosity of both types is 6 to 10%. Several cermets have been developed in an attempt to produce by this method heat resistant coatings having a high coefficient of expansion.

GEORGE F. COMSTOCK

Cast Structure of High Speed Steel

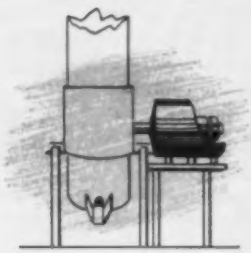
Digest of "Cast Structure of High Speed Steel", by E. Ineson and G. Hoyle, *Metal Treatment and Drop Forging*, Vol. 23, July 1956, p. 257-262.

THE COARSE CELLULAR carbide network which forms during the casting of high speed steel, particularly near the center of large ingots, is a major problem in the industry. At present, the only known effective method for its elimination is by extensive hot working with some 90 to 95% reduction of area. In ingots with poor carbide distribution, center bursting may occur. Even this method, however, will not suffice for ingots greater than about 14 sq.in. In an attempt to find a solution, the authors review the causes and effects in the light of recent knowledge.

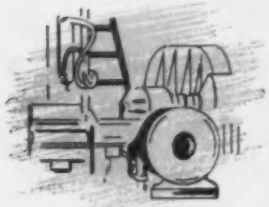
The basic high speed alloy is 18% W, 4% Cr, 1% V, with between 0.5 and 0.8% C. Kuo's version (*Journal* of the Iron and Steel Institute, Vol. 181, 1955, p. 128-134) of the constitution diagram of the Fe-W-Cr-C system at 18% W and 4% Cr is considered most representative.

When a crystallite forms from the melt, the total free energy change curve shows a maximum corresponding to a critical particle size. If the crystallite is smaller than this critical size, it will be unstable and tend to redissolve; if, however, it reaches the critical size, it will continue to grow. Therefore, any reduction in the "energy barrier" will lead to a refinement in the grain size. Undercooling reduces the critical nucleus size, and this assists refinement when the nucleation is homogeneous – that is, not affected by foreign particles or mold walls. (*Continued on p.* 140)

SLIDE GATE ACCURATELY CONTROLS AMOUNT OF AIR DISCHARGE
LONG LIFE, MINIMUM MAINTENANCE ASSURED BY WIDE CLEARANCES
RUGGED, LIFETIME CONSTRUCTION. ONE PIECE, ALL METAL CASING. CAST BRIDGE WORK.
PERFECT BALANCE OF IMPELLERS ELIMINATES VIBRATION, INCREASES LIFE OF BEARINGS AND PACKING
FOR DELIVERY OF HIGH VOLUME, LOW PRESSURE AIR
SPENCER
Turbo-Compressors are PREFERRED
by Equipment Manufacturers and for Replacement



CUPOLAS



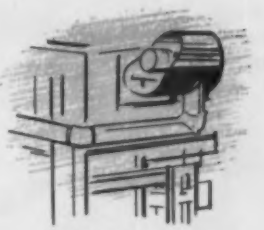
ROLLING MILLS

You'll see Spencer "blowers" . . . with the familiar "sugar-scoop" design . . . on a wide variety of equipment in foundries and metal-working plants everywhere.

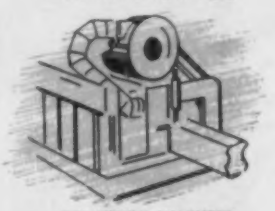
Performance is the reason. Experienced metals men know you *just can't beat* the rugged reliability, the proved-in-use performance of a Spencer Turbo.

Simple, built-to-last construction . . . mounting that requires no special foundation, no bolting down . . . discharge in any of eight positions . . . quiet operation . . . use of power proportional to amount of air used . . . these are a few of the reasons why *SPENCER is preferred.*

Capacities from ⅓ HP to 1,000 HP, up to 20,000 CFM, 4 oz. to 10 lbs. pressure.



ANNEALING FURNACES



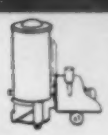
CONVEYOR WASHERS

SPENCER HARTFORD

The SPENCER TURBINE COMPANY
HARTFORD 6, CONNECTICUT

OTHER QUALITY SPENCER PRODUCTS

STATIONARY VACUUM SYSTEMS



PORTABLE VACUUM CLEANERS

PNEUMATIC CONVEYING SYSTEMS

HOW *Cambridge* Woven Wire Belts help Heat Treaters

increase uniformity, speed production

By providing continuous movement through heat treating cycles, woven wire conveyor belts eliminate batch handling, increase product uniformity and production capacity in annealing, brazing, quenching, tempering, sintering, etc. EXAMPLE:

Continuous Annealing

MOVING BELT carries a stream of brass light bulb ferrules through furnace for continuous uniform annealing at 1400° F.

OPEN MESH of Cambridge belt allows free circulation of heat around load so that hot spots are eliminated. Open mesh construction also permits rapid drainage in wet processes such as quenching and washing.

ALL-METAL BELT withstands heat up to 2100°F. (as in copper brazing) without damage, provides lasting strength because there are no seams, lacers or fasteners to break or wear.

SPECIAL RAISED EDGES hold parts on belt, are typical of a variety of side and surface attachments available to hold the product during flat or inclined movement.

Cambridge Woven Wire Conveyor Belts are made in any size, mesh or weave, from any metal or alloy, and can be used under a wide range of conditions . . . hot or cold, wet or dry. Call your Cambridge Field Engineer to discuss how you can cut costs with continuous processing on woven wire conveyor belts. Look for his phone number under "Belting, Mechanical" in the Yellow Pages or write for FREE 130-PAGE REFERENCE MANUAL.

The Cambridge Wire Cloth Co.

Department B, Cambridge 3, Maryland

WIRE CLOTH | METAL CONVEYOR BELTS | SPECIAL METAL FABRICATIONS

OFFICES IN PRINCIPAL INDUSTRIAL CITIES

High Speed Steel . . .

An alternative method of reducing the energy barrier is by inoculation with a foreign substance, which can act as a nucleation catalyst. For this to be effective, the substance must exist as small solid particles at the solidification temperature with a satisfactory degree of dispersion, must be wetted by the liquid, must possess sufficient attraction for the solid metal atoms, and should provide less than about 10% lattice misfits. A search for suitable inoculants for the delta phase in high speed steel is being made on the foregoing basis, but no results are presented.

A further approach to the problem is by the use of mechanical vibrations, at either sonic or ultrasonic frequencies. This technique has been successfully applied to the grain refinement of nonferrous alloys. The reasons for its success have been variously ascribed to the fragmentation of crystals by the frictional forces set up, to a form of cavitation which may occur at the mold wall, and to an increase in atom mobility with a corresponding increase in the probability of nucleus formation, particularly with ultrasonic frequencies. Unfortunately, this method has not as yet proved beneficial as far as high speed steel ingots are concerned. One preliminary experiment resulted in a banded structure which persisted in the forged bars.

R. C. A. THURSTON

Metals for Construction of Reactors

Digest of "Steel for Nuclear Energy", by R. C. Dalzell, *A.E.C. Monograph TID-8012*, July 1956, 6 p.

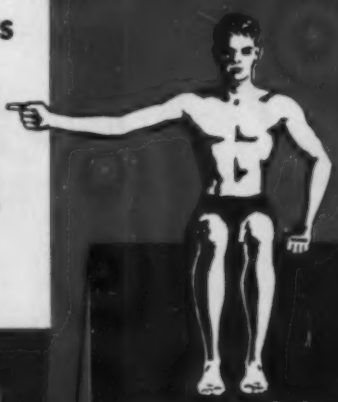
A MONOGRAPH recently issued by the A.E.C. discusses the present uses and probable future requirements for stainless steel and other metals for construction of atomic energy installations.

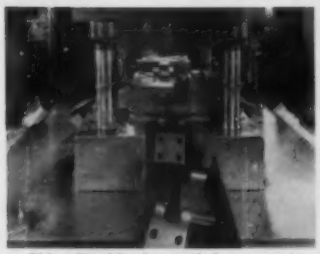
Although Type 347 stainless has been used in substantial quantities by the A.E.C., it does not necessarily follow that many reactors in the future will require a correspondingly large amount. All steels by virtue of their iron content, as well as

Leading hardware manufacturer prefers

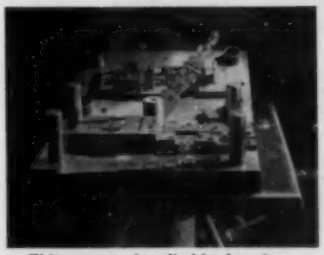
Olympic FM

DIE STEEL for long run dies

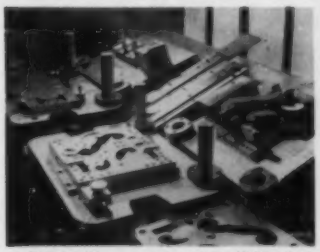




This die blanks and forms automotive door hinges of curled type from 5/16" steel. Production over 1,000,000 hinges yearly.



This progressive die blanks, pierces, and forms a new patented barrel bolt and keeper from 1/16" steel.



Braces for ornamental shelf bracket is blanked from .143" full hard 1010 steel that has been given a forged iron finish.

Millions of butt hinges per year are blanked out on this die. Metal thickness is 1/8".

For typical die applications such as these, McKinney Manufacturing Co., Pittsburgh, Pa. selects Olympic FM because of:

1. Reduced machining time
2. Increased tool life
3. Better finish . . . does not tear

McKinney Mfg. Co., manufacturer of hinges and builders' hardware since 1865, is one of many die users who prefer the long-run performance characteristics of Latrobe's Olympic FM high carbon-high chromium die steel. These performance advantages, together with economical machinability factors are the result of Latrobe's DESEGATIZED® process of manufacture where the carbide particles and the alloy sulphides are uniformly dispersed throughout the steel.

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Metals for Reactors . . .

other common strong metals such as nickel and copper, are to a certain degree undesirable in nuclear reactors because of their tendency to capture "slow" thermal neutrons. For instance, the thermal neutron absorption cross section, in terms of sq. cm. per g., is as follows: 0.0007 to 0.0015 for Be, Zr and Mg; 0.0049 for Al; 0.0072 for Cb; 0.015 for Mo; 0.026 to 0.046 for Fe, Cr, Cu and Ni; 0.07 for Ta and Ti; and 0.35 to 0.4 for Co and Hf.

In spite of the high values for Ta and Co, as compared with those for Cb and Ni, respectively, the effect of the small amount of the impurities Ta and Co that will be brought into Type 347 steel along with its Cb and Ni is insignificant in comparison with the high structural value of the steel because of its Fe, Cr and Ni content. Similarly, the presence of a little Be, Zr or Mg in the steel could not be of appreciable advantage from a nuclear standpoint in view of the effects of iron, chromium and nickel.

The reactor business is in need of corrosion resisting steels of higher yield strength than that of Type 304 and of high endurance limit to resist thermal cyclings.

Aluminum has been satisfactory for the construction of many reactors where corrosion at only moderate temperatures need be resisted. Magnesium does not resist corrosion by hot water well enough, and beryllium and columbium are considered too expensive.

Zirconium may often be worth its cost because of its excellent corrosion resistance and the economies possible in the reactor size and uranium requirement, due to its low neutron absorption of 0.001 sq. cm. per g. after removal of hafnium. It is difficult to decide between the use of zirconium or stainless steel, and the relative advantages must be calculated specially for each reactor. In some respects, the use of 30 times as much zirconium as Type 347 steel would be permissible in construction. Minor differences in composition of the steel are negligible with respect to nuclear effects, and the absorption cross section of all 18-8 steels can safely be taken as 0.03 sq.cm. per g.

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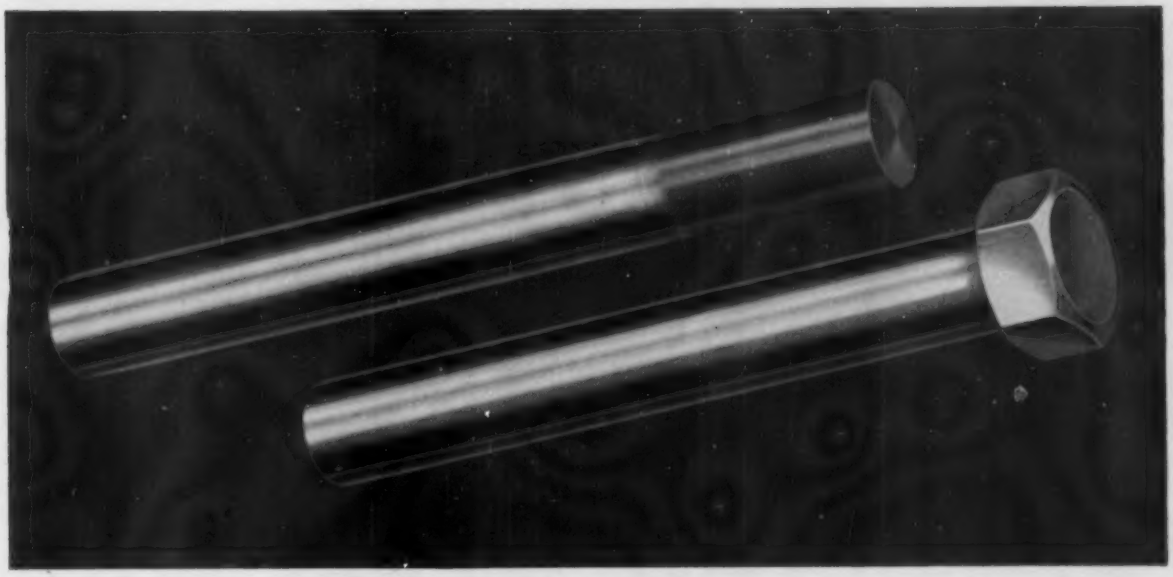
Die Life Increased Up To 400%

with TOCCO* *Induction Heating*



• Naval Bronze, Silicon Bronze, Copper, Aluminum, Monel and all types of stainless steel are heated for forging at the H. M. Harper Co., Morton Grove, Illinois. Regardless of material TOCCO can be profitably applied to brazing, heat-treating and forging operations in almost any metal-working plant.

Production Up—In addition to the very important savings in forging dies, TOCCO has increased production to as much as 265% of output possible with former heating methods. On the 1″ type 303 Stainless machine bolt blanks shown here TOCCO upped production from 75 to 200 parts per hour, using 35 K. W., 10,000 cycles.

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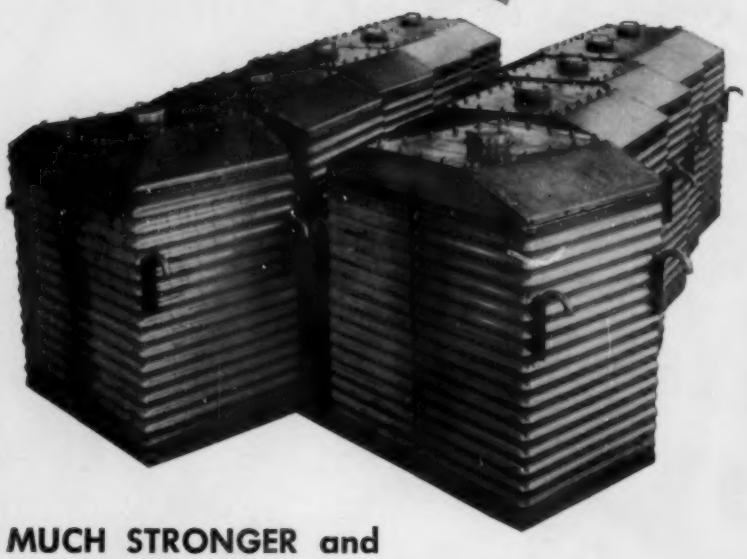

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All the advantages of lighter weight, rapid heat transfer, easier handling and lower over-all cost are inherent in this Rolock-perfected construction technique. Yet there is no sacrifice of strength or anticipated performance. In fact, vessels such as those shown above, of Type 316 Stainless Steel, can be expected to out-perform alternative designs in every way.

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Flow Brightening of Electrolytic Tin Plate

Digest of "The Alloying of Tin and Iron during Flow-Brightening of Electro-Tin-plate", by J. C. Thwaites, *Journal* of the Iron and Steel Institute, Vol. 183, July 1956, p. 244-253.

THE PURPOSE of the flow-brightening studies was to obtain data on the rate of intermetallic compound formation. Specimens of a 0.085% C low-alloy steel for tin plating were plated with various amounts of tin from an electrolytic cell which simulated conditions in an industrial tin-plate line. The electrolyte used was an acid stannous phenolsulphonate type, and the plating was carried out on cathodically cleaned and pickled steel samples at a current density of 100 amp. per sq. ft. The electrolyte was pumped through the cell at a rate of 600 ft. per min. to minimize concentration polarization. Flow brightening of the plated samples was carried out by electric resistance heating.

Several variables were investigated. These were heating rate, total time of heating, maximum temperature before quenching, and time at temperature before quenching. Further experiments were carried out in oil baths to determine the rate of alloying at temperatures below the melting point of tin. Surface reflectivity of the flowed samples was measured in an effort to follow the surface smoothness as a function of flow-brightening temperature and plate thickness.

A large number of samples plated had mean total tin coating weights of 2.8, 5.7, 8.3 and 11.0 g. per sq. m. The specimens were heated at 280° F. per sec. for preset times and the peak temperature attained by each was recorded. Iron-constantan thermocouples welded to the specimen surface were used for this measurement. Bright finishes were obtained in the range 500 to 715° F. The amount of alloy formed was measured by the coulometric method of Kunze and Willey. Typical values for samples heated to 625° F. in 2.5 sec. showed that for 2 g. per sq. m. of alloyed tin, about 1.3 g. per sq. m. free tin remained on the external surface. Further studies at heating rates of 40 and 100° F. per

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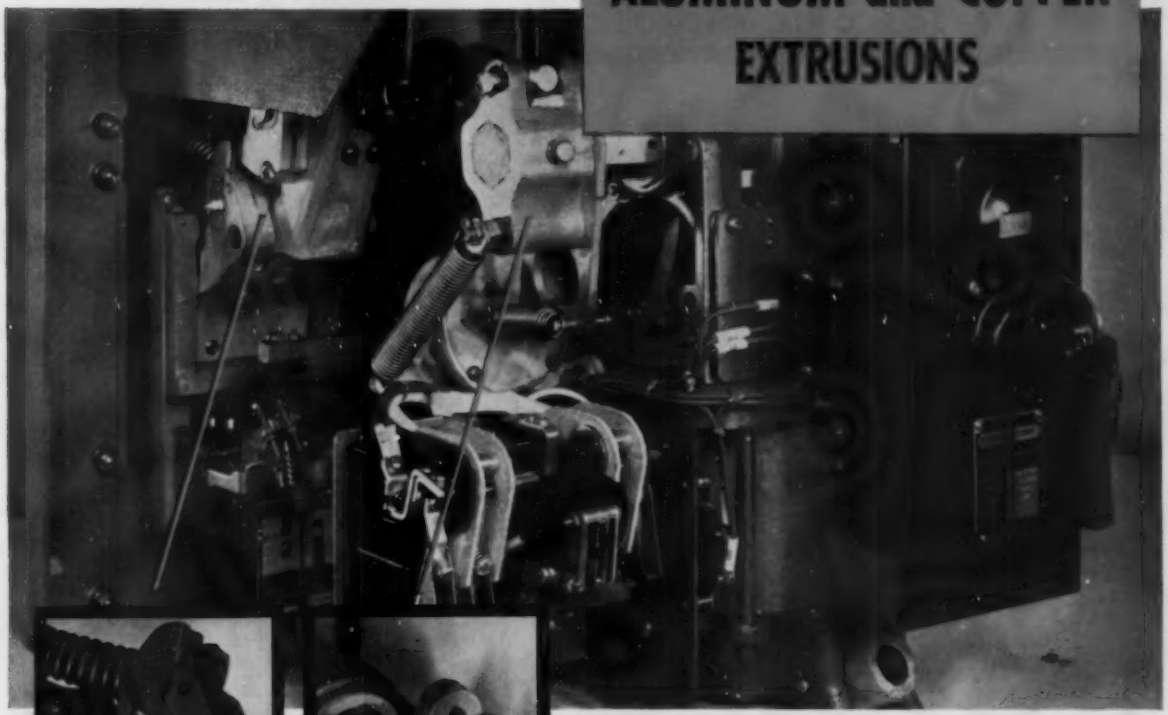
I-T-E CIRCUIT BREAKER—KD (3,000 amp. rating) showing progressive assembly with Revere Copper and Aluminum Extrusions in place. I-T-E Circuit Breaker—KE is same type with 4,000 amp. rating.



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ALUMINUM
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—form a Money-Saving team in latest

I-T-E CIRCUIT BREAKERS

Revere T. A. Service an Important Factor in Ultimate Design of Parts

The larger of the two extruded and drawn copper shapes shown at extreme left started out on the drawing board as two pieces. It was thought that a single shape of this size could not be made satisfactorily. At this point, I-T-E Engineers got together with Revere's T. A. (Technical Advisory) Service and threshed things over. The final result is the one-piece extrusion shown and a reduction in machining time.

Aluminum was selected for the other extrusion shown because I-T-E found that it cost less per pound of metal and had a higher strength ratio when compared to a casting. Also, space was a factor. In all, Revere supplies 5 copper and 2 aluminum extrusions for KD and KE type I-T-E Circuit Breakers. All were designed to fit specific requirements of I-T-E Engineers. Where it could be used satisfactorily, aluminum was applied because of economy, while current carrying members called for copper.

This is still another example of Revere supplying the metal that will do the best job and with the greatest economy . . . be it aluminum, copper or any one of their alloys. So, with new things happening all the time in non-ferrous metals it can pay you to keep in close touch with Revere.

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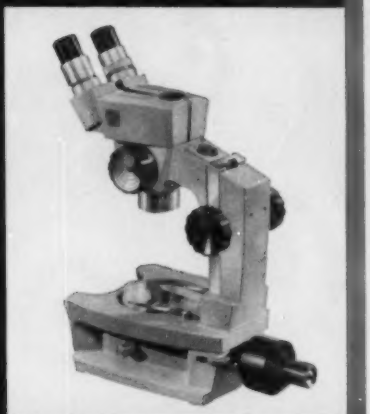

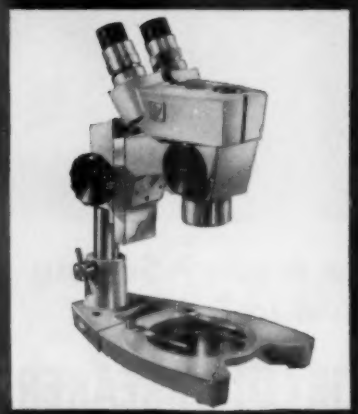

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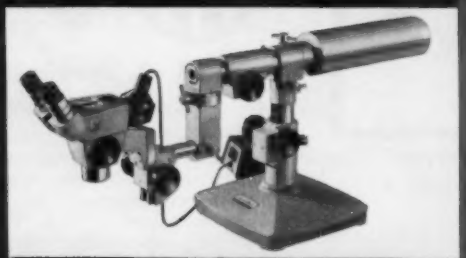

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Tin Plate . . .

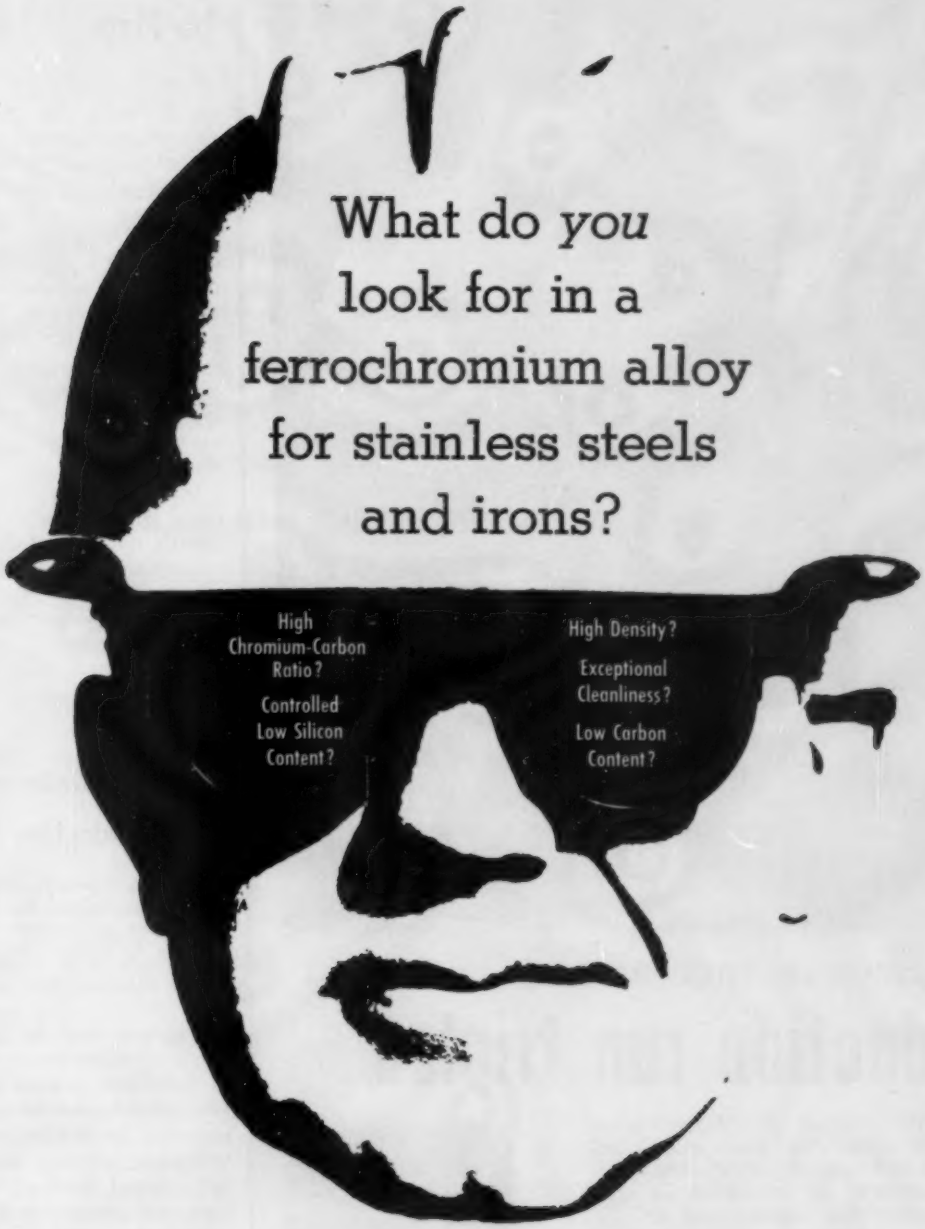
sec. revealed that the amount of alloy increased with decreasing heating rate for any given peak specimen temperature.

The effect of holding for periods up to 30 sec. on samples heated at 100° F. per sec. showed that at temperatures near 480° F. alloy growth was complete in 5 sec. On other samples heated at 100° F. per sec. but held at 570° F., the alloy coat increased steadily over the entire 30 sec. Diffusion temperatures below the melting point of tin also allowed alloy growth to take place. Measurements between 345 and 435° F. for times up to 100 min. on previously flow-brightened plates showed that solid state alloy growth could be as effective as growth in the presence of a liquid phase.

Typical alloy layers in the experimental tin plate averaged 3 to 12 μ in., and taper sectioning was used in hopes of being able to see the alloy layer metallographically. This method was unsuccessful and a preferential solution of free tin in NaOH solutions was finally used to reveal the alloy layer. The appearance of the alloy later was dependent mainly upon its thickness and not on the heating conditions under which it was formed.

Examination of the external tin surfaces showed that on the thin plates having only 2.8 and 5.7 g. per sq. m. of total tin, the surfaces were bright and smooth up to flow temperatures of 750° F. On the thicker coatings the tin coat did not remain uniform but coalesced into individual globules leaving intervening areas without free tin. This tendency was called "de-wetting" and was very pronounced at elevated temperatures. Where flowed-unflowed interfaces existed in partially melted samples a sharp transition existed at the common interface. Underlying ferrite grain boundaries neither were the prominent nuclei for melting nor were found regularly at the flowed-unflowed interfaces. One general feature of the tin coatings was an increase of grain size with an increase in flow-brightening temperature.

Measurements of the surface reflectivity of flow-brightened samples were made by comparing the amount of specularly (direct) reflected light



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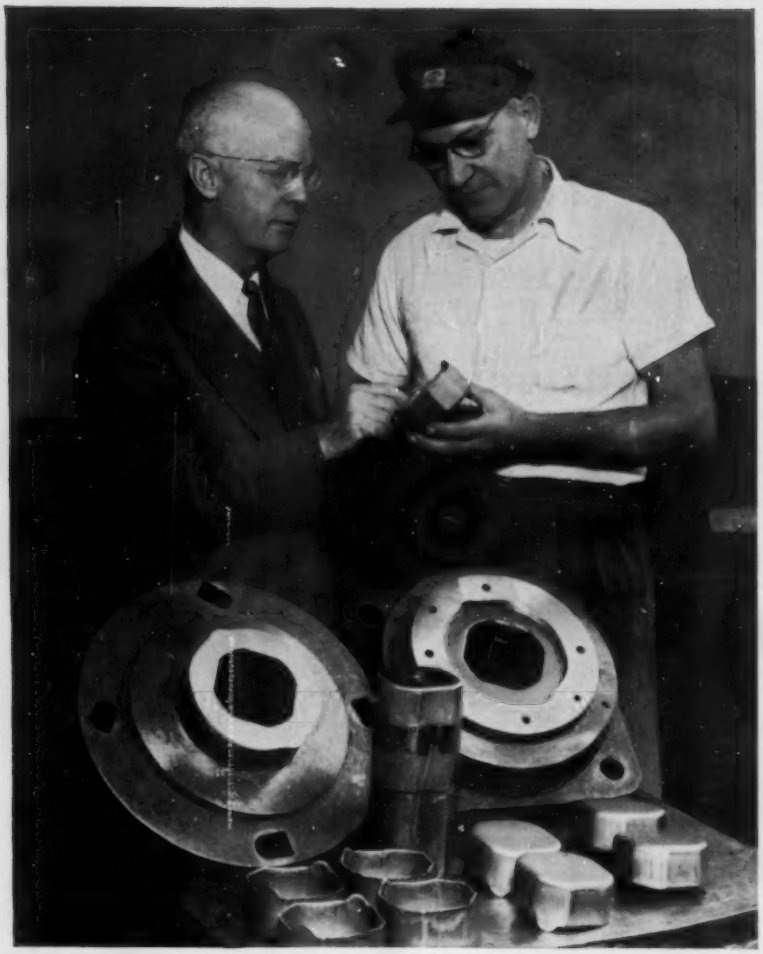

Solving problems with VULCAN Tool Steels:

Production run tripled

Until recently, a run of 200,000 switch boxes on a double-acting draw press was an accepted standard at Steel City Electric Company, Pittsburgh. The compound die used in this single-stroke blanking and drawing application is subjected to severe abrasion. The boxes come off the press hot.

Under pressure for greater production, Vulcan Alidie tool steel was used for the complete tooling set-up. 688,000 boxes were produced in one tool run. Inspection proved that the run could have gone even longer.

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Jesse Casasanta, tool and die supervisor, Steel City Electric Company, calls the performance of Vulcan Alidie Tool Steel in this test "a near miracle."

HKP VULCAN CRUCIBLE STEEL DIVISION
H. K. PORTER COMPANY, INC.

Tin Plate . . .

(S) to the total light (T) reflected and diffused. The ratio S/T goes through a maximum when plotted against flow-brightening temperature, because at elevated temperatures oxidation of the tin becomes appreciable. A typical value of the as-plated S/T ratio was 0.1 while the peak S/T ratio after flow brightening was about 0.9. One anomaly was that the plate with 8.3 g. per sq. m. tin consistently gave the brightest appearance to the naked eye, but the reflectometer measurements in no way confirmed this observation.

One disappointing feature of the study was the author's failure to identify the intermetallic compound which was grown during flow brightening. While the evidence points to $FeSn_2$ the presence of FeSn could not be discounted, especially in samples reacted above 925° F.

RICHARD E. GRACE

Oxygen Determination in Production Steels

Digest of "The Aluminum Reduction Method for the Determination of Oxygen in Steel", by J. E. Wells, *Journal* of the Iron and Steel Institute, Vol. 184, October 1956, p. 185-187.

ANALYZING steel for oxygen content by conversion in a vacuum of the oxides present to alumina, followed by acid extraction and estimation of the alumina, is not a new technique, but there have recently been several worth-while modifications and refinements. The original workers took samples of liquid steel, killed them with excess aluminum additions and recovered the alumina by acid extraction.

In the current research, use has been made of mullite refractory tubes, better able to withstand necessary temperature and pressure conditions than silica tubes previously employed. The new tube design has made possible the fusion of two samples at a time, as well as the application of temperatures up to 2370° F., thus increasing the number of determinations possible in a given time.

Essentially, the apparatus com-

prises a mullite tube 24 in. long and with 1-in. internal diameter, accommodating two graphite boats and the samples. One end of the tube is closed, the other sealed with a rubber bung coated with silicone vacuum grease. The bung is fitted with a glass tube connected to a U-tube pressure gage and a two-way tap for connecting the apparatus to the mechanical oil pump for evacuation.

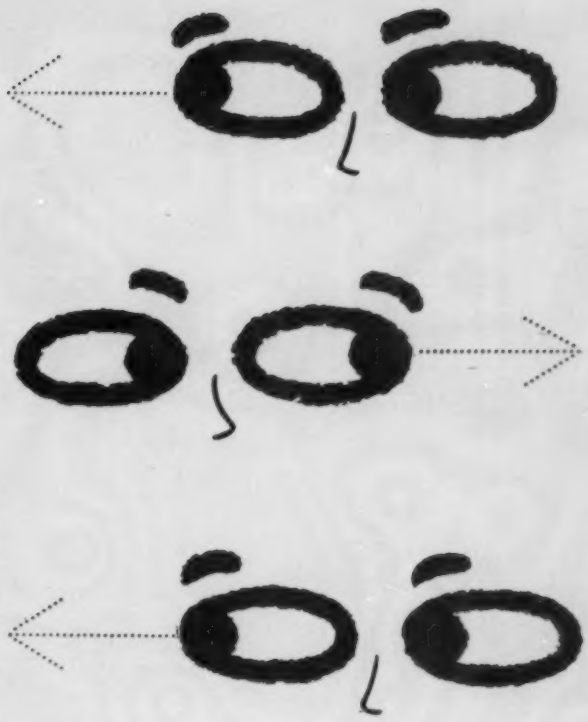
Sample boats are 3 in. long with wall thickness of ⅛ in., machined from a half-section of a 1-in. diameter bar of graphite. The tube and its contents are heated in an electric rod-element furnace 12 in. long. Sample steel disks about 0.1 in. thick are cut from a bar which has been ground to remove surface oxide. Disks are washed in ether just before the determination. Aluminum is prepared by cutting pure sheet ⅛ in. thick into suitably sized strips which are filed lightly on all surfaces before use.

Degassing of the graphite boats precedes the oxygen determination. Four of them – two containers and two lids – are placed in the refractory tube which is then sealed and evacuated until the pressure falls to 1 or 2 mm. Hg. The tube next is placed in the furnace which is switched on and controlled at 2280° F. for 1 hr. The furnace then is cooled to 1700 to 1800° F. and the refractory tube withdrawn. At this point a second tube can be placed in the furnace and four more graphite boats degassed similarly.

When the first tube is cold, air is admitted, the boats withdrawn and any deposit on them is removed with a wire brush. Approximately 10 g. of sample, sandwiched between aluminum strips weighing about 14 g., is placed in each boat and the lids set in position before returning to the refractory tube. After evacuation and setting in the furnace, temperature is raised rapidly to 2280° F. and held for 2 hr. Following cooling to about 1750° F. the tube is withdrawn again and placed in an asbestos rack. Care must be taken to maintain the tube horizontal to avoid spilling the molten aluminum.

When the tube and contents become cold, air is admitted, the boats are removed and the samples are extracted for determination of

(Continued on p. 152)



Alternating stresses bear watching!

Back and forth . . . up and down . . . in and out . . . if those stresses keep changing, the life of a metal part is a hard one . . . and often a short one. Stress reversals can cause "fatigue" failure at stresses far below the expected strength of the metal.

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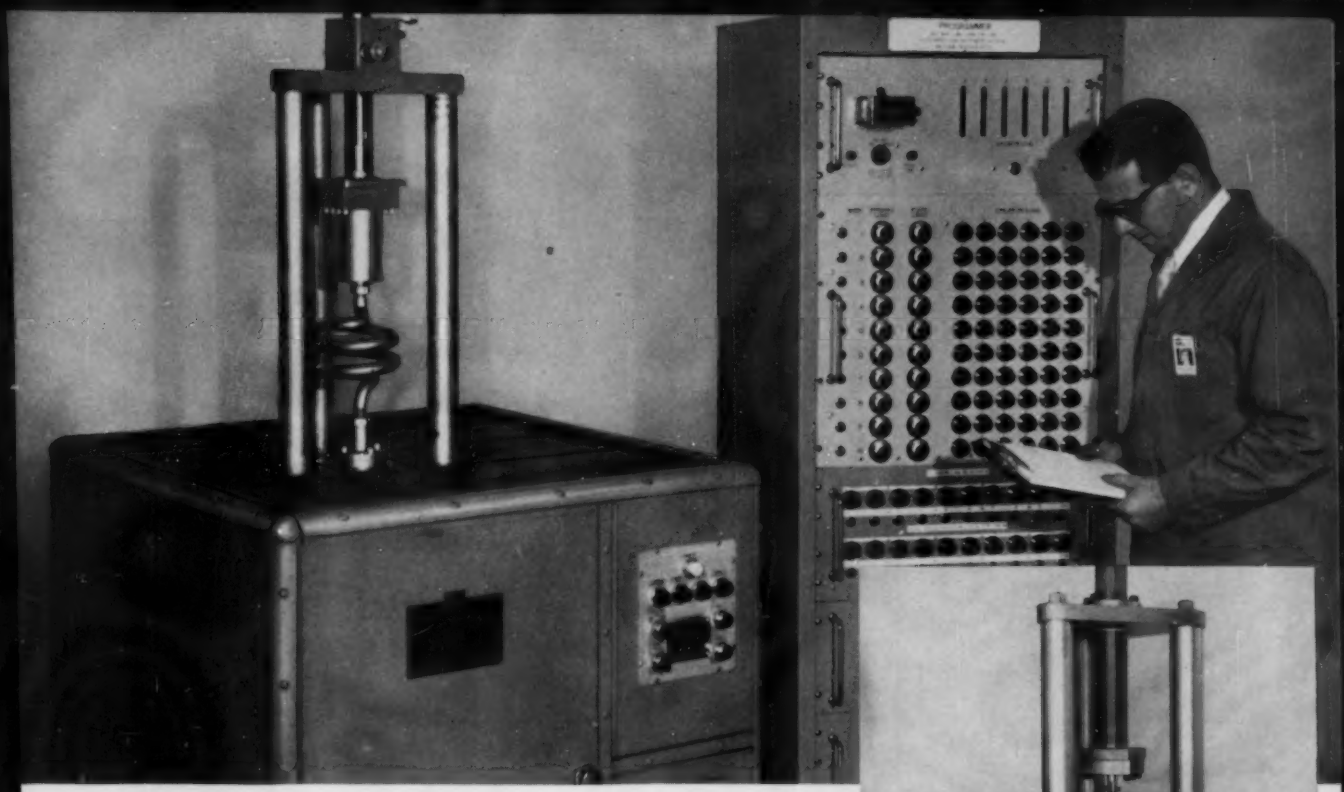

The Baldwin SF-1-U Universal Fatigue Machine shown here is being controlled by the Baldwin Programmer at its side. Entire sequences of varying static or dynamic loads can be run off, all in one automatic operation.

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Add a Baldwin Programmer to your Baldwin SF-1-U Fatigue Machine, and you have testing automation! Complete test sequences can be set up on the programmer controls and run off on the fatigue machine without supervision. Varying static or dynamic loads, for any predetermined number of cycles are possible. Loads can be changed at approximately 500 lb. per min.

For the best in testing, see Baldwin first . . . choose from a complete line of equipment for testing compression, tension, creep, fatigue, impact or torsion. Write today and ask to have a Baldwin representative call on you.

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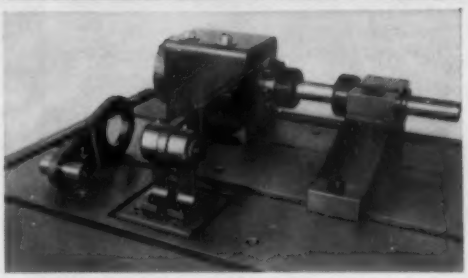

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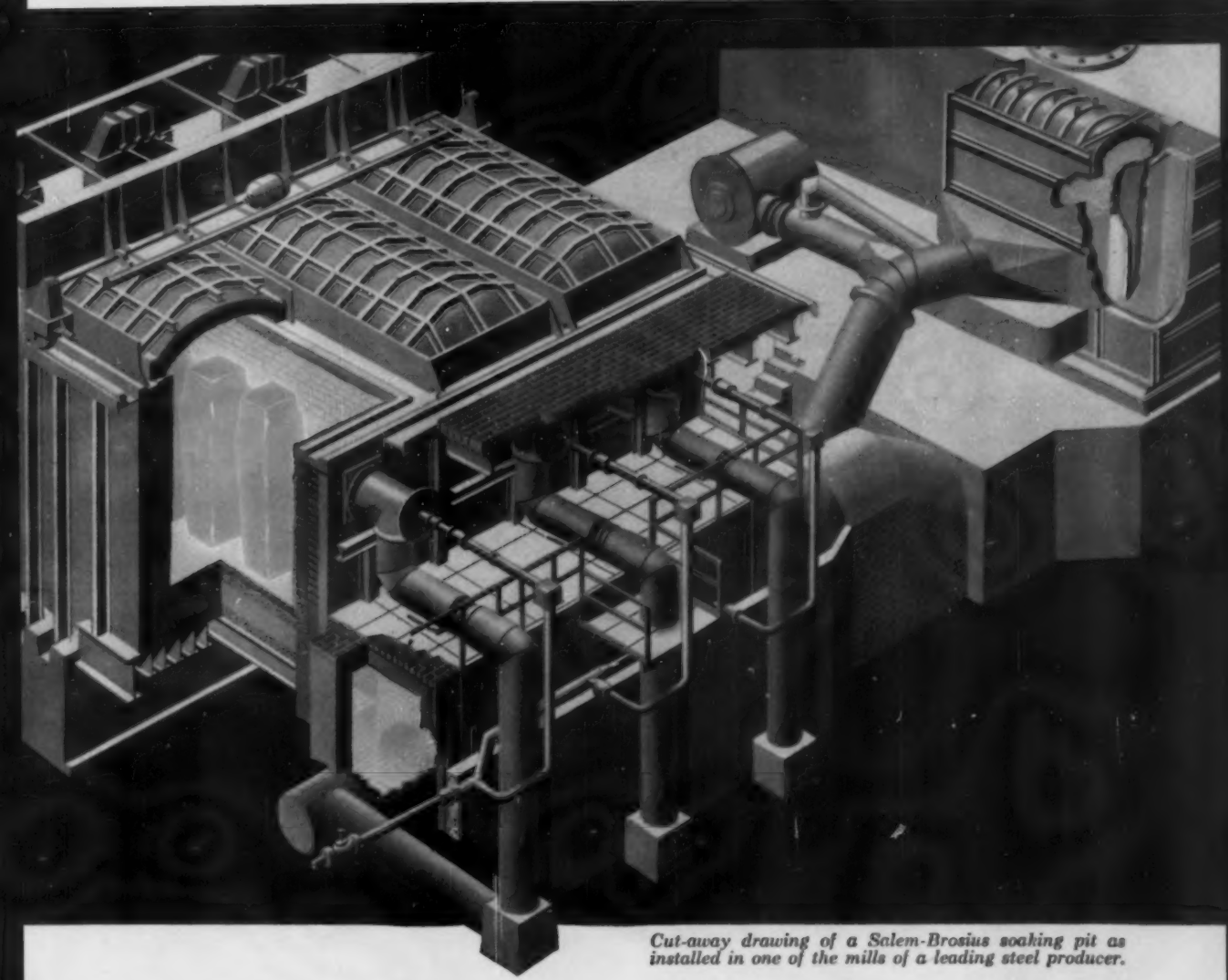

Cut-away drawing of a Salem-Brosius soaking pit as installed in one of the mills of a leading steel producer.

Users are the best salesmen of Salem-Brosius soaking pits

"We have again specified Salem-Brosius soaking pits for our expansion program," reports an operating official of a major steel company using pits installed by several manufacturers. "The previous installation heated more steel ingots ready for rolling with less fuel consumption, less maintenance cost, and better temperature uniformity than any other type of pit in our plant."

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Oxygen in Steel . . .

alumina. The boats, after wire brushing, can be reused at once.

In using this method of oxygen determination, several precautionary measures are advisable:

1. Only freshly degassed boats should be used.
2. Exposure of degassed boats to air should be kept at a minimum.
3. Samples and aluminum should be freshly prepared.
4. Furnace temperature should be maintained in the range of 1700 to 1800° F. when the refractory tubes are inserted or withdrawn, in order to speed up the determination and to minimize any loss of oxygen as carbon monoxide from rimming and semikilled steels.

A "blank" is determined by fusing 14 g. of prepared aluminum sheet with a small weight of steel of known low oxygen content. Its calculated oxygen, after a test, is deducted from that determined in the sample. Determination of alumina follows standard chemical procedures for acid extraction, filtration, ignition and weighing.

The aluminum reduction method, operated in a vacuum, gives results which compare well with those obtained by the vacuum-fusion method — which is considerably more expensive in terms of equipment.

Some doubt exists about the applicability of the technique to rimming and possibly semikilled steels, in view of the ease with which carbon monoxide is evolved from some steels when heated in vacuum.

ARTHUR H. ALLEN

Soldering and Brazing

Digest of "Soldering and Brazing of Metallurgical Materials", by R. C. Jewell, *Journal* of the Birmingham Metallurgical Society, Vol. 36, June 1956.

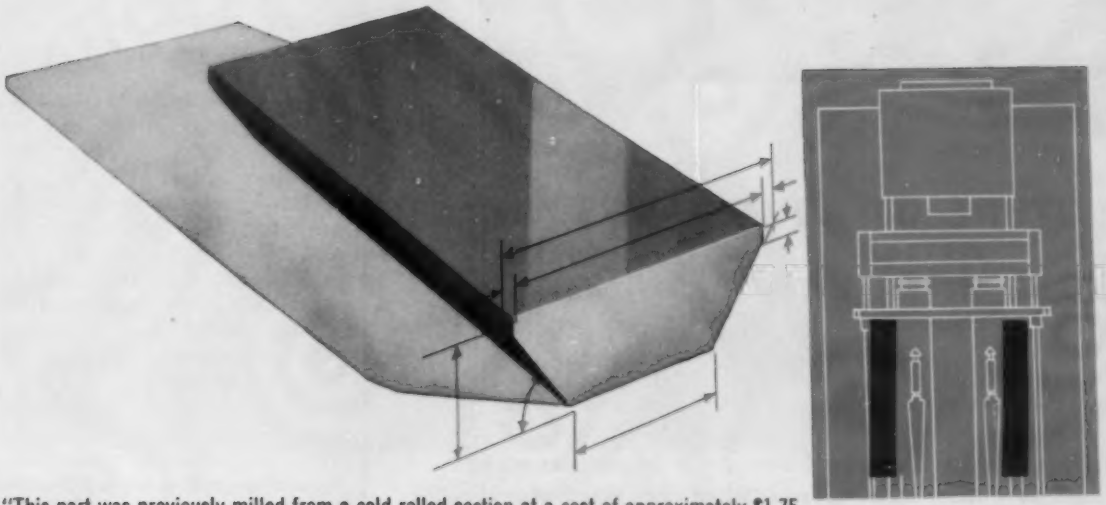
THE AUTHOR defines soldering and brazing as methods of joining in which the filler metal is fused while the parent metal is not. He proposes that a dividing line between soldering and brazing should be establishing, based on temperature, and suggests 1020° F.

The effectiveness of a solder depends upon its ability to spread into the joint, the rate of spreading

J&L hot extruded cold drawn cam rail section

cuts machining cost

from $1.75 to 75¢ per foot



"This part was previously milled from a cold rolled section at a cost of approximately $1.75 per running foot. Our present cost is 75¢ per foot using your cold drawn extruded section." This machine tool manufacturer cut his production costs by buying these exclusive J&L steel sections. You can obtain similar savings:

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3. Eliminate cost of casting and forging intricate sections.
4. Reduce inventories because extrusions are quickly available.

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This is an actual photo of a surface prepared by polishing and etching a cross-section of a forging, to reveal the "grain flow." (x2)

A PICTURE OF ADVANTAGES YOU CAN GET ONLY FROM FORGINGS

In the picture above you see the grain flow in a forging.

This picture demonstrates two things. First, the metal is dense and free from porosity. The impact or pressure of forging helps make it so. Such density is important when parts must have machined surfaces, when they must provide reliable strength and safety, and when they must be tight against leakage of liquids or gases. This quality reduces rejects and saves money. It contributes to safety and saves lives.

Second, notice how grain flow lines follow the shape of the part. This improves impact resistance and fatigue strength of the part. In closed-die forging, these flow lines can be positioned, to give maximum properties where they are needed. As a result, forged parts can be lighter, safer, stronger, and frequently less costly.

Thus this picture shows you why forged metal is *metal you can trust.* You can trust forgings for performance, and to save money. Find out how forgings can improve your products, your costs. Consult a *Forging Engineer*, and send for the booklets offered below.

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Soldering & Brazing . . .

being controlled by the contact angle and the way this angle is changed by alloying or flux action. For brazing, an additional factor is the rate of alloying between the molten filler material and the parent metal. The principles upon which brazing depends are the operating temperature, time, rate of heating, rate of alloying or diffusion, joint clearance, joint design and the properties of the filler alloy and the material being joined.

Fluxes play a vital role in both soldering and brazing. The flux cleans the parent metal, promotes weldability and preserves the clean surface to permit the filler alloy to flow.

Special noncorrosive organic fluxes for soft soldering of aluminum and aluminum alloys have recently been developed in England. For hard soldering these materials, a new flux has recently been introduced for use with "Thesscal" hard solders. It is corrosive and must be washed off after use. For low-temperature brazing alloys, fluoride-based fluxes of low melting point are essential. These too are corrosive. For high-temperature brazing alloys, borax or borax-based fluxes are most suitable. They are practically noncorrosive. Vapor fluxes such as boron trifluoride have been successfully used in the aircraft industry. Controlled atmospheres may be used as fluxes or fluxes can be eliminated by brazing in a vacuum.

The "Thesscal" process for light metals is entirely new. It uses hard solders and a flux applied with a torch. The important feature of the process is the corrosion resistance of the joints. These solders are the first to win Ministry of Supply approval for use on aluminum and aluminum alloys. The process may also be used to join aluminum to dissimilar metals such as copper, bronze, mild steel and stainless steel. The melting range of the solders lies between 790 and 950° F. and the strength of lap joints ranges from 11,000 to 45,000 psi.

Two additional processes for aluminum and its alloys have been introduced. The "Kynal" process uses a noncorrosive flux and results in shear strengths of 4500 to 5500 psi. The second employs a special

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MAY-FRAN

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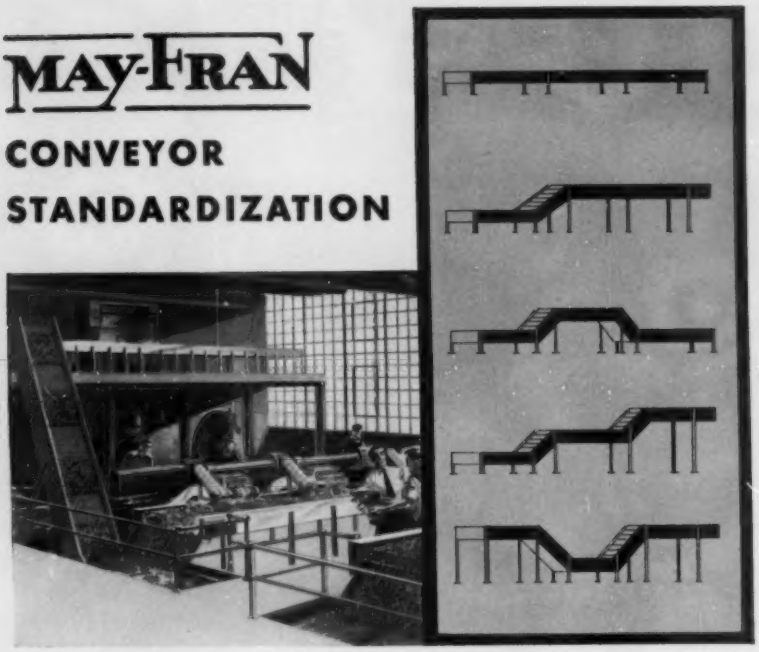

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7320-MF

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Soldering & Brazing . . .

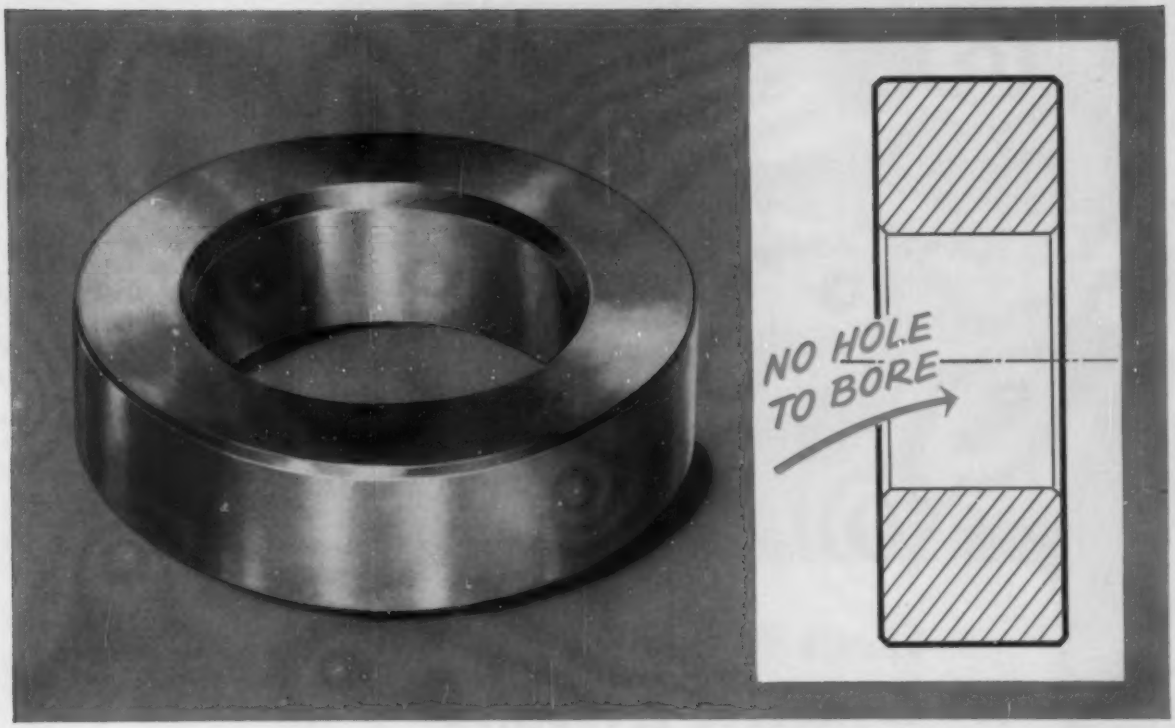
tool having refractory bristles which mechanically "tins" the parent metal with a special fluxless soft solder. Shear strengths in lap joints of 5500 psi. are obtained after 200-hr. exposure to saturated water vapor at 212° F.

A new brazing material has been introduced for brasses, bronzes, nickel alloys and steels. The filler alloy, known as "Dimpalloy", is prefluxed. It can be supplied in strips and stampings. Blanking or punching will not disturb the flux coating and the material can be stored indefinitely without deteriorating. This alloy has also been approved by the Ministry of Supply for steel parts in small production. It avoids the human element in fluxing and can be supplied in various grades to suit various brazing temperatures.

The Nimonic alloy series may be brazed with strong ternary silver-palladium-manganese alloys. One such alloy gives short-time shear strengths of 11,000 psi. at 1470° F. and has a creep strength of 4500 psi. for prolonged periods up to 1470° F. "Nicrobraze", a nickel-chromium-boron alloy developed in the United States, melts at 2155° F. and relies on diffusion with the parent metal to change the composition and so raise the ductility of the joint. Since diffusion varies with time and temperature, the properties of the joint will vary with these factors. However, the high-temperature properties of Nicrobraze are very attractive.

Gray cast iron may be silver brazed where the American "Kolene" process is used to clean and prepare surfaces for brazing. This treatment removes flake graphite and impurities from the surface. These claims were verified by tests conducted by the author.

For steels, the low-temperature silver brazing alloys have been very satisfactory, but suffer the disadvantage of a corrosive flux. Fluxless brazing alloys containing lithium are now under development and this field appears very promising. Brazing of carbide tips to tools has been greatly simplified by use of a tri-metal, consisting of a copper layer in the middle, with silver alloy brazing faces on both sides. This is an



Steps up gear blank production 300% by switching from bar stock to TIMKEN® steel tubing

AN engine manufacturer felt that his gear blanks were costing him too much to make. The center hole had to be bored out of solid bar stock. It took a whole hour to turn out 29 blanks. And a lot of steel was wasted in the process.

So the manufacturer discussed his problem with metallurgists of the Timken Company, experts in fine alloy steel. After study they recommended a change in production methods together with a switch to Timken® seamless steel tubing in place of bar stock.

With Timken seamless steel tubing, the center hole is already there. It doesn't have to be bored out. Finish boring was the engine maker's first production step. And with Timken steel tubing his gear blanks are now being turned out at 120 to 130 an hour—an increase of 300%.

Machining costs have been cut by more than half. And because the center hole is "built-in", no steel is wasted.

The files of the Timken Company contain records of hundreds of problems that have been solved by Timken fine alloy steel. If you have a tough steel problem, why not bring it to us? Wire, write or phone The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

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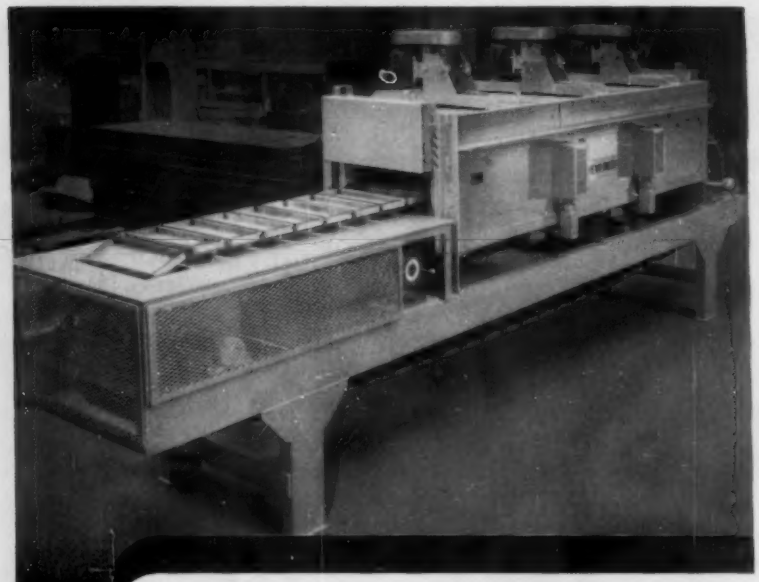

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CONVEYOR FURNACE

Of special design for Kohler Co. of Kohler, Wisconsin, this Hevi Duty Conveyor Furnace is being used to heat aluminum and brass billets prior to forging jet engine and other parts. Not only has this furnace been designed for a specific job, but Hevi Duty Engineers also built into this furnace many additional features.

- Notice the three fans which speed the heating of the billets by circulating the heated air, and also assure a uniform temperature in the heating chamber. With this feature, a smaller, more economical furnace is able to do this production job.
- Heat resistant alloy conveyor links and trays mean years of dependable service.
- Versatility . . . by using a variable speed drive to adjust the conveyor speed, this furnace can be used for annealing, tempering, and other heating operations.

Special Hevi Duty Furnaces can be engineered to your specifications and your production system. Let us know your requirements. Our engineers will work with you.

HEVI DUTY ELECTRIC COMPANY
MILWAUKEE 1, WISCONSIN
Heat Treating Furnaces... Electric Exclusively
Dry Type Transformers *Constant Current Regulators*

Soldering & Brazing . . .

American development. For tools which get very hot in service (above 1110° F.) a new brazing alloy known as "R.D.", which is age hardenable at 1110° F. and has high hot strength, is particularly useful.

Finally, the newer metals of importance to the atomic energy industry are considered. Zirconium has not been brazed successfully on a practical scale. Beryllium is difficult to braze and uranium still more so. Columbium may be brazed by plating with nickel or copper, diffusing and then brazing in a normal way. Molybdenum can be brazed with copper or nickel-rich brazing alloys quite successfully. Furnace brazing with silver-palladium-manganese filler alloys in hydrogen has been reported as successful. Tantalum can be vacuum induction brazed with nickel or copper-gold.

H. J. NICHOLS

Uranium—Threshold of Revolution in Power?

Digest of "Uranium for Fuel", by Eugene B. Hotchkiss, *Ordnance*, Vol. 40, March-April 1956, p. 901-904.

ATOMIC ENERGY, as now known and signifying chiefly the fission of uranium, has opened the road to a new era for electric power generation. It may be expected to revolutionize many methods in industry, medicine and agriculture.

This is true in most informed opinions, despite statements in some quarters that the process of atomic fusion (the hydogen bomb principle) may some day replace fission as the greatest potential power source. For example, Lewis L. Strauss, chairman of the Atomic Energy Commission, has said, "In regard to the use of fusion materials rather than fissionable materials, we have never yet been able to control the fusion energy releases. Commercial use of fusion materials is part of the long-range development of 20 or more years hence."

The two natural fissile materials are uranium and thorium. A third — plutonium — is a man-made product of uranium fission. Even thorium is not yet a full-fledged com-

petitor to uranium, requiring its combination with uranium for fission in certain types of reactors.

Looking ahead to power requirements of the world for the next 100 years, an estimate has been made that by the year 2050 there will be a demand for some 1250 energy units (1.0×10^{18} Btu. each). At present, all fossil fuel sources, together with water power, total less than 100 such units. However, there is available in atomic energy fuel, an estimated 1500 units, and this reserve is said to be 23 to 25 times as great as the fossil fuel reserve.

In addition to conventional sources of energy now in use, the tremendous quantity delivered to the earth by the sun must be recognized. One calculation is that the quantity of solar energy available each day is equal to around 20 million of the Hiroshima-type atomic bombs. Beyond this, vast quantities of latent power exist in the energy of the tides and in the force of the winds.

Acknowledging that uranium is likely to become a principal source of electric power, it is of interest to know the obstacles in the path of its progress. One is the matter of sources for uranium ores. They include the Belgian Congo, Canada, Australia, Portuguese Africa, and extensive United States deposits. The problem of milling or concentrating uranium ores is complicated by the fact that more than 175 uranium minerals are now recognized, many not yet completely identified.

First job of the metallurgists and miners is to break down the minerals and get the uranium into solution. This may call for acid leaching, solution in carbonates or other methods. Most ores are quite lean and large quantities of gangue must be handled to extract the uranium; each type is apt to exert its own malevolent influence over the extractive process, either through excessive reagent consumption or by gumming up the processing circuit.

One common way of recovering uranium is to precipitate it as an insoluble compound. Recently ion-exchange techniques have been used, and most of the more recent mills in the United States and Canada employ this method. There are now nine such mills operative in the

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Heat Treated in...

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Allis-Chalmers of Milwaukee is using Hevi Duty Controlled Atmosphere Furnaces to heat treat tools and dies made from high carbon, high chrome steels, 18-4-1, molybdenum, and cobalt high speed steels. Maintaining the exact surface carbon content of the tools and dies during heat treating is achieved with —

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- A Hevi Duty Box Type Hardening Furnace, designed for temperatures to 2000° F., is used for preheating high speed steels and hardening carbon steels.
- A Hevi Duty High Temperature Furnace, designed for temperatures to 2600° F., is used to harden the high speed steels.

This combination assures you that tools and dies can be treated to exact hardness. Achieve better heat treating results by specifying Hevi Duty Furnaces. Write for Bulletin 153.

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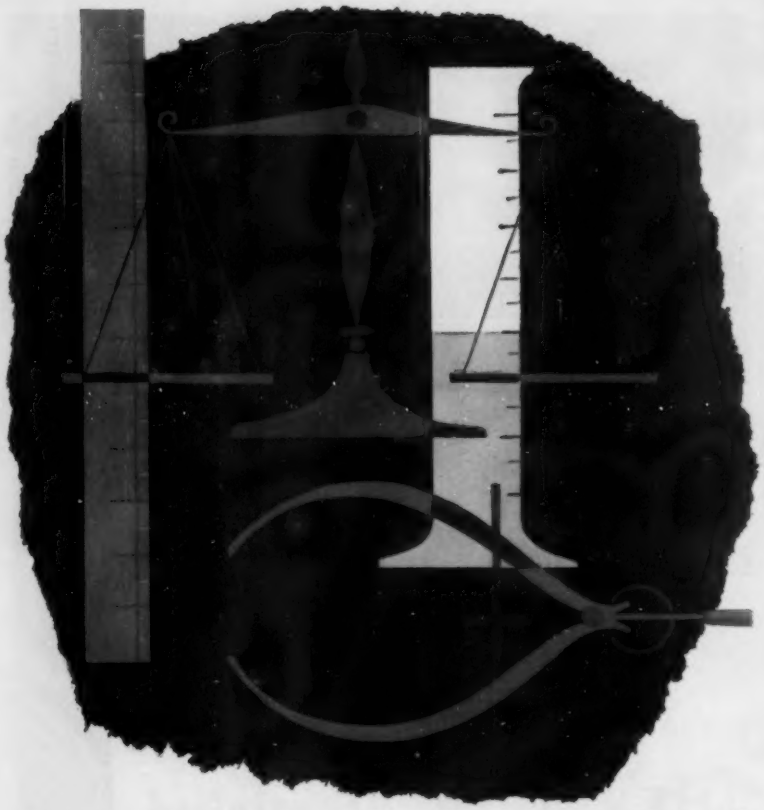

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Uranium Fuel . . .

United States, with several more under construction.

Crude concentrates of uranium from milling operations require considerable subsequent refining in order to achieve the necessary high purity before reduction to metal. This phase of the current program is being carried out by industry under government contract, although in the future, refining activities may be opened to industry generally.

The next step is the fabrication of reactor fuel elements. This is done to rigorous specifications and with metals often difficult to form or join. A high degree of skill is demanded in special techniques, such as alloying, cladding and joining.

Recycle material from a reactor must also be fabricated, along with virgin material and, given sufficient decontamintaion, may be handled similarly.

The final step in preparation of fission fuels is reprocessing, an important aspect of the economy of nuclear power reactors which has not received the attention it should. The term means the reprocessing of spent fuel elements and the separation and refabrication of the recovered valuables into fresh fuel.

A nuclear reactor, as now constituted, is a furnace in which suitable fuel is fissioned to release heat, accompanied by fission products. Some of the latter unfortunately tend to inhibit the essential chain reaction — they "poison" the reactor. Also, there are physical deterioration and dimensional changes in the fuel element to contend with, caused by the high localized energy release of the fission products in the fuel elements.

The future of atomic eneregy lies with uranium, whether or not it is supplemented to some extent by other fuels and whether or not the processes of fission later may be supplemented by the little-known processes of fusion, or solar energy.

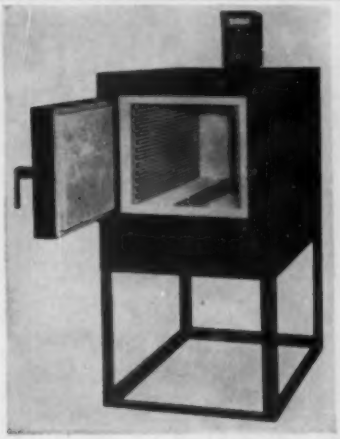
Atomic power development will take plenty of time and labor, and money. The implied duty of U.S. researchers is to attempt to harness this wonderful new giant — a far greater resource than petroleum which made its appearance at the turn of the century.

ARTHUR H. ALLEN

Metal Progress

Bulletin Board...

The Buyers Guide For Metals Engineers



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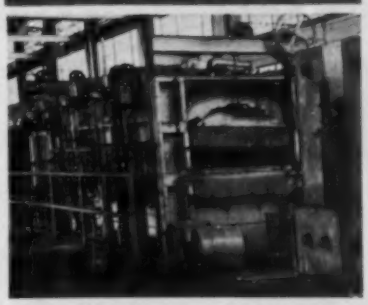

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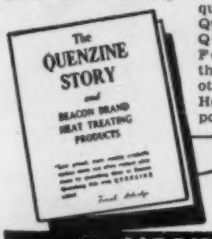

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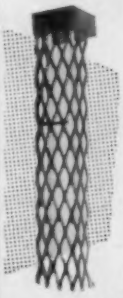

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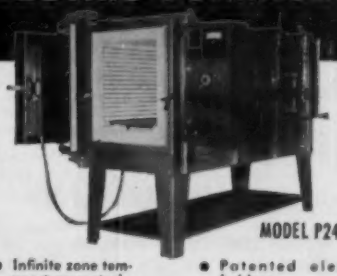
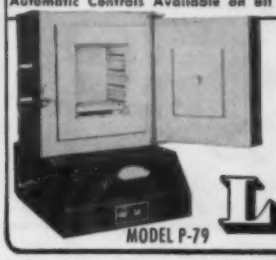
dyna-trol ELECTRIC FURNACES

MODEL NO.	FIRING CHAMBER (H.W.D.)	PRICE (300° to 2000°)	PRICE (400° to 2300°)
P46	4½"x4½"x6"	$90.00	$110.00
P79	6"x6"x9"	$205.00	$225.00
P918	9"x9"x18"	$480.00	$528.00
P414	14"x14"x14"	$525.00	$603.25
P124	12"x12"x24"	$715.00	$822.25
P818	18"x18"x18"	$775.00	$887.50
P136	18"x18"x36"	$1125.00	$1312.50

Automatic Controls Available on all Models



MODEL P2472-1



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- Zone temperature indication by Pyrometer Selector Switch.
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OVER 40 STANDARD MODELS • WRITE FOR LITERATURE

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Grade "B"
FERROUS METAL PROCESSING
Eliminates . . .
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ROUND, SQUARE, FLAT AND HALF-ROUND WIRE FOR MASS PRODUCTION OF SMALL PARTS

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Other Non-ferrous Alloys
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Available with hot-tinned finish for solderability.
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THE ULTIMATE LUBRICANT FOR EXTREME HEAT AND PRESSURE APPLICATIONS

ANTI-SEIZE has uncompromising lubricating qualities at temperatures minus sub zero and up to 950 F. It is so versatile no maintenance man or industrial plant should be without it.

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...famous for the "MOLYLUBE" Series

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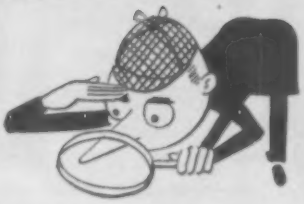

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This new service on used heat treating equipment is completely without obligation to you. To receive the latest availabilities just drop us a line requesting to be placed on our mailing list for a monthly digest. What are your production requirements?

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NOT GRAY
NOT FADED
NOT MOTTLED
BUT RICH, DARK, UNIFORM
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Liquid Carburizer— For a tougher, more durable case!

SWIFT HEAT

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METAL CLEANING PICKLING and PLATING COMPOUNDS

Acid additives, brighteners, bright dips and chromate conversion coatings!

Send today for literature and technical data sheets.

THE Swift INDUSTRIAL CHEMICAL CO.
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CHROMIZING PROCESS COMBATS...
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WEAR
CORROSION

CHROMALLIZING diffuses chromium into the surface of iron and steel parts, providing the corrosion resistance of stainless steel and the wear resistance of chromium carbides. CHROMALLOY Case cannot chip, peel or flake.

Chromalloy Corporation is fully equipped for processing large or small quantities of parts. Engineering advisory service available.

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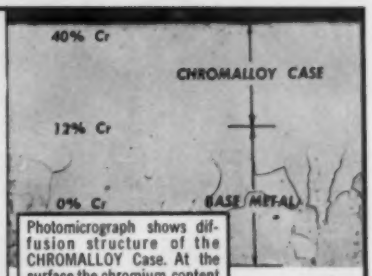

Photomicrograph shows diffusion structure of the CHROMALLOY Case. At the surface the chromium content is 35% to 45%.

Chromalloy CORPORATION
451 Tarrytown Road, White Plains, N.Y.
Telephone White Plains 6-0020

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DO YOU HAVE AN IDEA...

THAT SOME FUNCTIONAL METAL PART COULD BE MADE BETTER OR CHEAPER BY ALUMINUM EXTRUDING?

Bring your idea to specialists in adapting aluminum extrusions to new functional parts applications. G. E. I.'s engineers are ready to consult with you, without obligation, on one part or a million.

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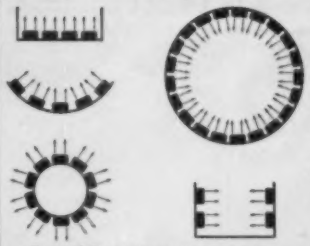
ULTRASONIC CLEANING



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Transducer Radiating Areas of ¼ sq. ft. to 10 sq. ft. — for use in solvents and detergents.

Eliminates hand operations — Reduces rejects in plating, finishing, assembly.

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Specializing in Ultrasonics Since 1946

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DESIGNERS & BUILDERS OF SPECIALIZED METAL CLEANING EQUIPMENT

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- Degreasing
- Anodizing
- Pickling
- Plating
- Heat Treating
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ANY SIZE AND SHAPE • ANY DUCTILE METAL

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THE C. O. JELLIFF MANUFACTURING CORP.

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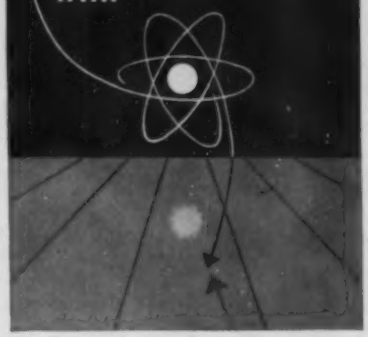
equips you to Electroplate Precious Metals with



SCIENTIFIC PRECISION

Technic, Inc. equips you with controlled apparatus and electroplating solutions to maintain exacting standards and close tolerances. Typical benefits are the spectacular economies Technic effects in handling gold — where often electroplaters lose up to $60,000 or more of every $100,000 worth through outmoded equipment, inefficient methods and solutions.

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Technic engineers design and install your equipment — and stand by until performance is assured. *No installation is complete without this follow-through.*

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Technic Potassium Gold Cyanides, Concentrated Aqueous & Dry • Technic Electroplating Solutions: Rhodium, Platinum & Palladium • Technic Immersion Tin • Technic Protectox Anti-Tarnish • Technic Flame Flux

TECHNIC EQUIPMENT

Technic Electroplating Systems • Technic Germanium Diode Rectifiers • Technic Turbomatic Agitators • Technic Electroplating Barrel Unit • Automatic Techni Timers

TECHNIC BIBLIOGRAPHY

Technic publications, authoritative in our field: "Electroplated Gold"; "Precious Metal Electroplating Data: Gold, Rhodium, Palladium, Platinum, Silver, Nickel", "Electroplated Platinum"; "Electroplated Palladium"; "Electroplated Rhodium"; "Analysis of Gold & Gold Alloy Solutions".

Consult us without obligation, whether in respect to a new installation and electroplating solutions, or an existing system now in use. Write for Technic publications in your field of interest.

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Chicago Office—7001
North Clark Street

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THE LARGEST ENTERRRISE OF ITS KIND IN THE WORLD

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NEW pocket size thickness gauge

ELCOMETER

Measures Non-Magnetic Coatings with ± 5% ± .0001″ Accuracy

ELCOMETER measures thickness of porcelain enamel, paints, platings, foils, glass, paper, plastics, and other non-magnetic coatings quickly and accurately. Gauges flat or curved surfaces and hard-to-get-at spots easily. Needle locking device assures correct reading every time. Complete with tough leather case containing inner pocket for test strips. Weighs only 6 oz. Completely self-contained. Retail price: $68.00 F. O. B. Cleveland.

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Aluminum and Zinc

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TENSILKUT

Patent Pending

Accurate test specimens machined from sheet and plate materials .0005 to .500 in., in less than 3 min.

SIEBURG INDUSTRIES, INC.
Horse Plain Rd. • New Britain, Conn.

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by N. E. Woldman

This up-to-the-minute book lists over 19,000 alloys by trade name and gives their properties, compositions and typical applications. All important commercial alloys are shown.

1056 pages of valuable information, generous index and tables of manufacturers and the trade names of their products.

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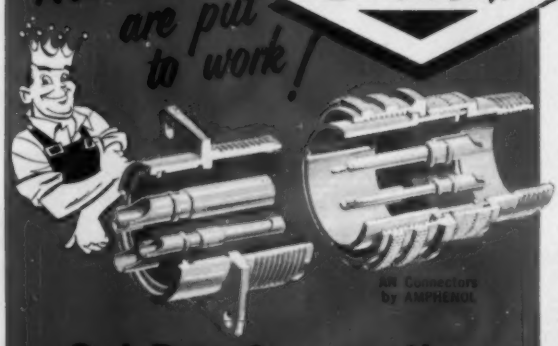

Sel-Rex Corporation
Precious Metals Division

Precious Metal Processes
FOR INDUSTRIAL APPLICATIONS

Developed *specifically* for industrial application, Sel-Rex Precious Metals offer many advantages over conventional processes. *One gram* of Sel-Rex BRIGHT GOLD, for example, *does the job of 2 grams* of regular 24 K. gold, because the deposits are more dense and twice as hard. Gives mirror bright finish directly from the bath, regardless of thickness requirements — eliminates costly scratch brushing, buffing and burnishing.

Sel-Rex BRIGHT RHODIUM meets the need of today's precise engineering applications with A. S. C. — Automatic Stress Compensation — a special technique which counteracts the high stress characteristics of conventional precious metal electroplates. Non dusting Sel-Rex Silver SOL-U-SALT is added directly to the plating bath, eliminating time consuming filtering or mixing — a cost cutting advantage exclusive with Sel-Rex.

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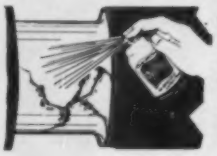
DYELINE INSPECTION PROCESS



Dyeline—a new two-stage inspection process for all non-porous materials. No skilled operator or expensive equipment necessary! Just spray Dyeline, follow with Dyeline Detector, and the exact location, type and extent of defects appear sharply and clearly on an opaque background!

No solvent required—water removes Dyeline immediately.

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ZIP RUST STOPPER #1 Protects metal parts for storage.

ZIP RUST STOPPER #2 Protects parts left in machinery for further processing; removes fingerprints.

ZIP PATTERN LAYOUT FLUID—Shows up scribed patterns strongly.

ZIP STENCIL INK—Quick drying—excellent on cartons and metals.

ZIP BELT LUBE—Prolongs belt life; promotes safety and speed.

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HARDNESS TESTING SHORE SCLEROSCOPE

Pioneer American Standard Since 1907

Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

SHORE INSTRUMENT & MFG. CO., INC.
90-35M Van Wyck Exp., Jamaica 35, N.Y.

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KENTRON

MICRO HARDNESS TESTER

Applies 1 to 10,000 gram loads

Write for Bulletin

Kent Cliff Laboratories Div.
The Torsion Balance Company
CLIFTON NEW JERSEY

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Determines the initial, basic stiffness or resilience of sheet and wire specimens, including cellophane and metal foil. Eight test ranges provide wide application, up to 100X. Test length, angle of deflection, rate of loading all standardized for accurate results between laboratories. Scale calibrated in gram centimeters.

TABER *Abrasion* **TESTER**

Tests wear resistance of metal, plastic, paint, rubber, leather, paper, foil, etc. With average technical experience, anyone can make a scientific, comparative abrasion resistance test with this instrument.

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SOLVED with

MAGNETIC ANALYSIS MULTI-METHOD EQUIPMENT

Electronic Equipment for non-destructive production inspection of steel bars, wire rod, and tubing for mechanical faults, variations in composition and physical properties. Average inspection speed 120 ft. per minute.

Over 80 installations in steel mills and fabricating plants.

MAGNETIC ANALYSIS SPECIAL EQUIPMENT

Electronic Equipment for non-destructive production inspection of both nonmagnetic stainless and high temperature steel bars and tubing—seamless or welded—as well as non-ferrous bars and tubing. Mechanical faults, variations in composition and physical properties are detected simultaneously. Average inspection speed 200 ft. per minute.

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Electronic Instruments for production sorting both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

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Electrical Equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

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Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

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MICRO-REFLEX
HARDNESS TESTER
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with CARL ZEISS Optical System
Measurements: to 0.0001 mm. . . . Observations on Ground Glass . . . Projection: to 0.001 mm. . . . Many Unique, Very Important Features.
INVESTIGATE!
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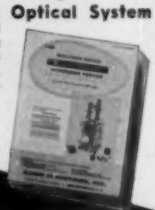

GRIES INDUSTRIES, INC.
Testing Machines Division
NEW ROCHELLE 3, N. Y.

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THE NEW
DERMITRON
NON-DESTRUCTIVE
COATING THICKNESS TESTER

FAST
ACCURATE
PORTABLE
COMPACT
DIRECT-READING

- *For Metals on Metals*
- *Non-Conductors on Metals*
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You can now have 100% inspection of production of nearly any possible coating on almost any base—including the first and only accurate, direct readings of such combinations as zinc, cadmium, copper on steel; silver on brass; copper on zinc; anodizing on aluminum; organic coatings on non-ferrous metals—without the use of chemicals.

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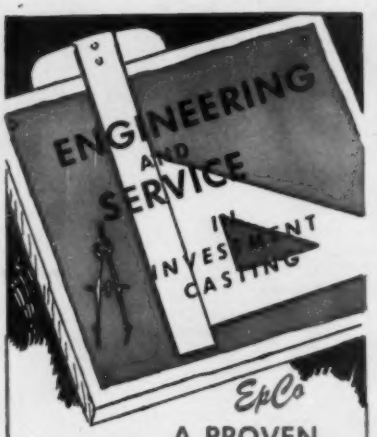

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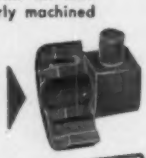
A PROVEN
DEPENDABLE SOURCE
FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

INVAR CASTING Special Feature—Nickel content held to 35% minimum—36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.



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IN 10 SECONDS!

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Complete Arc Welding Accessories
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Automatic Welding . . .
- All Analyses
- Coated, Straightened
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Ask the Man Who KNOWS Stainless Welding . . .

Call Mr. Electrode . . . His years of experience and leadership in providing the correct—

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• Hairpin Hooks • Sheet Crates

• Steam Jets • Chain

• Mechanical Bar, Tube and Coil Picklers

THE YOUNGSTOWN WELDING & ENGINEERING CO.

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Grade "C-W-25"

Non-flammable

Non-toxic

Aqueous Oily Film Protects Ferrous Parts for Long Periods Indoor Storage

Write for free sample and brochure Specify Grade "C-W-25"

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BOSTON 16, MASS.

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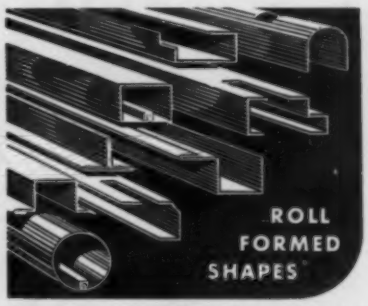

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- No acid pickle or bright dip.
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your comprehensive independent mill source of magnesium alloy Tubes • Rods • Shapes • Bars Hollow Extrusions • Plate • Sheet • Pipe • Wire • Welded and Riveted structures and assemblies

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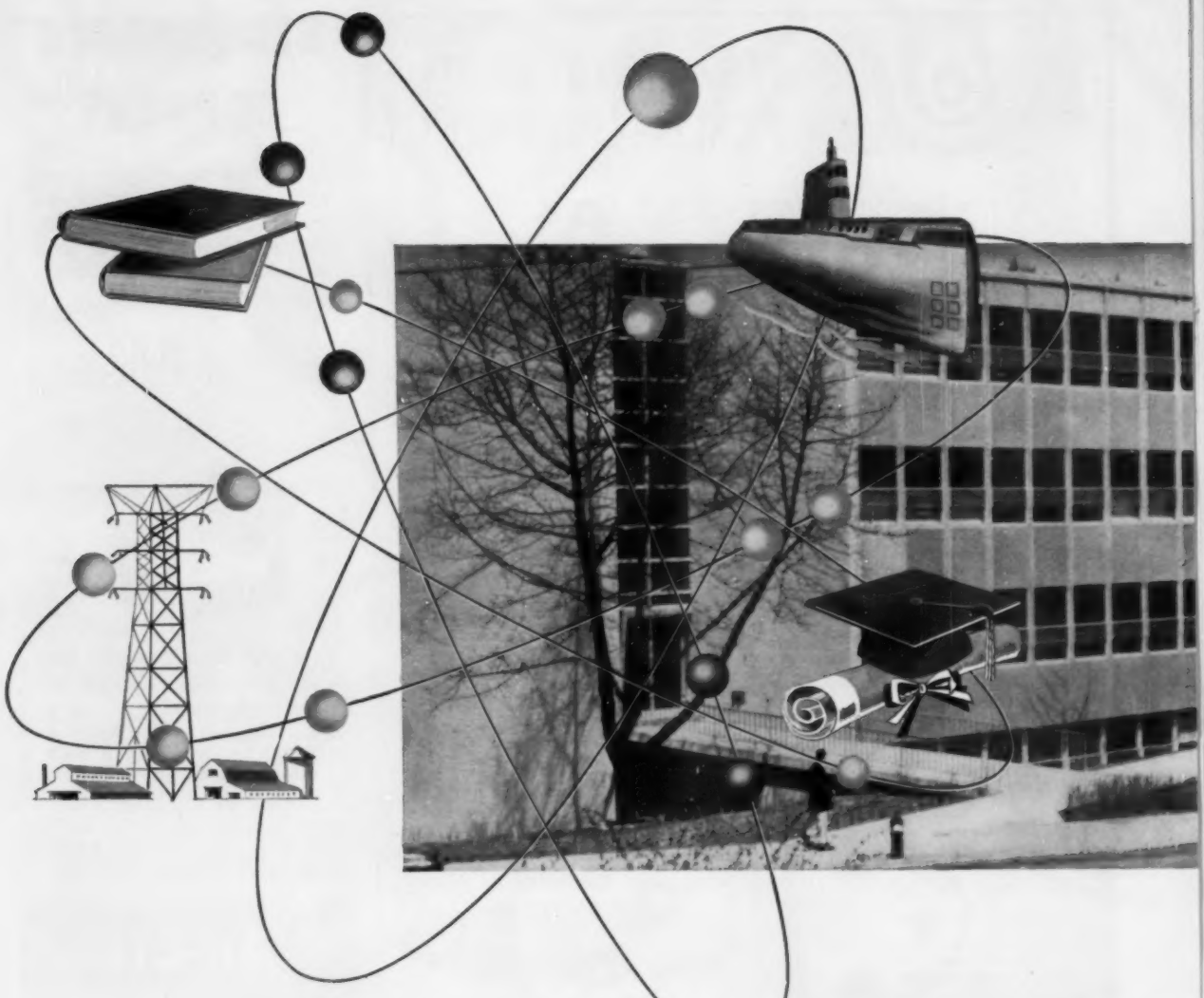

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The reactor core for the Shippingport Atomic Power Station

metallurgical engineers

In addition to these projects, Westinghouse metallurgists are conducting basic research in areas such as solid phase transformation, corrosion kinetics and mechanisms and the effects of irradiation on metals. At the Carnegie Institute of Technology, the fellowship recipient will develop an individual course of study to complete his doctoral program which may or may not be related to his area of work interest. Furthermore, he will be eligible for salary increases and professional advancement just as if he were working full time.

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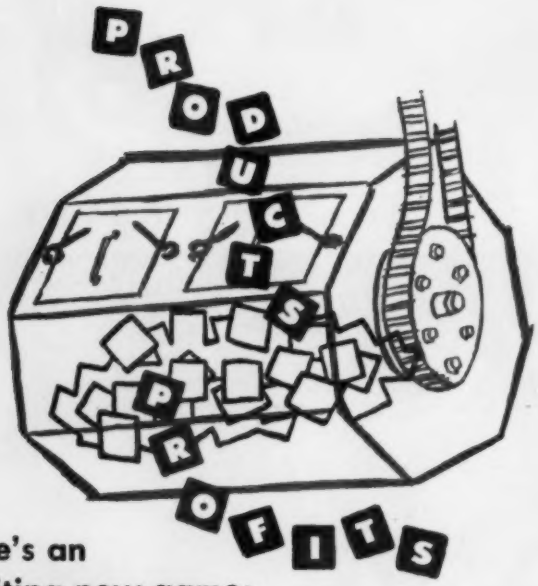

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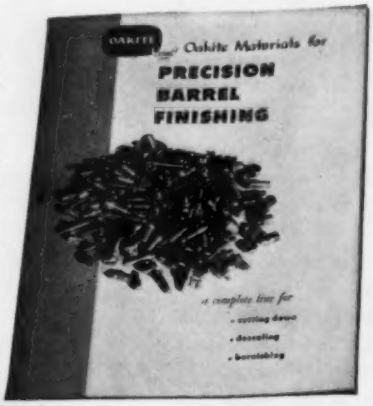

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Fabrication of Thorium Powders

Digest of "Fabrication of Thorium Powders", by W. W. Beaver, K. G. Wikle and J. G. Klein, *Journal of Metals*, Vol. 8, April 1956, p. 445-454.

THE POSSIBLE VALUE of thorium in the field of nuclear power through the transformation of Th^{232} to U^{233}, which is a fissionable element, affords a potential use far in excess of its present limited applications in alloys and in electron emissivity devices.

The authors discuss the methods of recovering thorium metal through calcium reduction of the oxide and of the chloride, and by electrolysis. Conversion of metal chips or turnings of the hydride is also feasible as a means of forming particles which can be converted to metal. The hot filament method is also applicable to thorium.

A variety of forms of thorium were prepared for study. They included castings, chips, ground powder, hydrided powder, calcium-reduced powder, and electrolytic flake. Except for the commercial hydrided powder, all were about 98% thorium, and the hydrided powder was 95 to 96% thorium. Calcium was less than 0.01% except for about 0.05% in the calcium reduced powder. Beryllium and iron were below a few hundredths, while carbon ranged from 0.05 to 0.2%. Thorium oxide ranged from 1 to 2%, except in calcium-reduced powder and electrolytic flake where it was 0.2%. In particle size, there were several fractions. Saw chips varied between 10 and 100 mesh; attritioned chips were from 35 to 200 mesh; commercial hydrided and calcium reduced powders were below 325 mesh; electrolytic flakes were from 35 to 200 mesh; and experimental hydrided powders varied from 35 to 250 mesh.

At approximately 30,000 psi. compacting pressure, the hydrided powders compacted more densely. The fine calcium-reduced powder, which compacted well at pressures to 180,000 psi., was matched only by the 35-mesh chips. The electrolytic flakes compacted best of all at all pressures.

Sintering served to densify the fine fractions to a high degree, and

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Thorium Powders . . .

hot pressing did likewise. Sintering temperatures of 2200 to 2550° F. served for densification with erratic results above that range. Extrusion at low temperatures using reduction ratios as low as 2:1 densified most of the sintered and hot pressed compacts to maximum. The commercial hydrided powder was the only type that could not be extruded. The authors favor the vacuum hot pressing process as giving powder of more uniform properties than were obtained with cold pressing. Also, there is more latitude in the choice of metals for the pressing dies.

The authors conclude that the techniques of powder metallurgy offer distinct economic possibilities for both primary and secondary thorium powders.

LINCOLN T. WORK

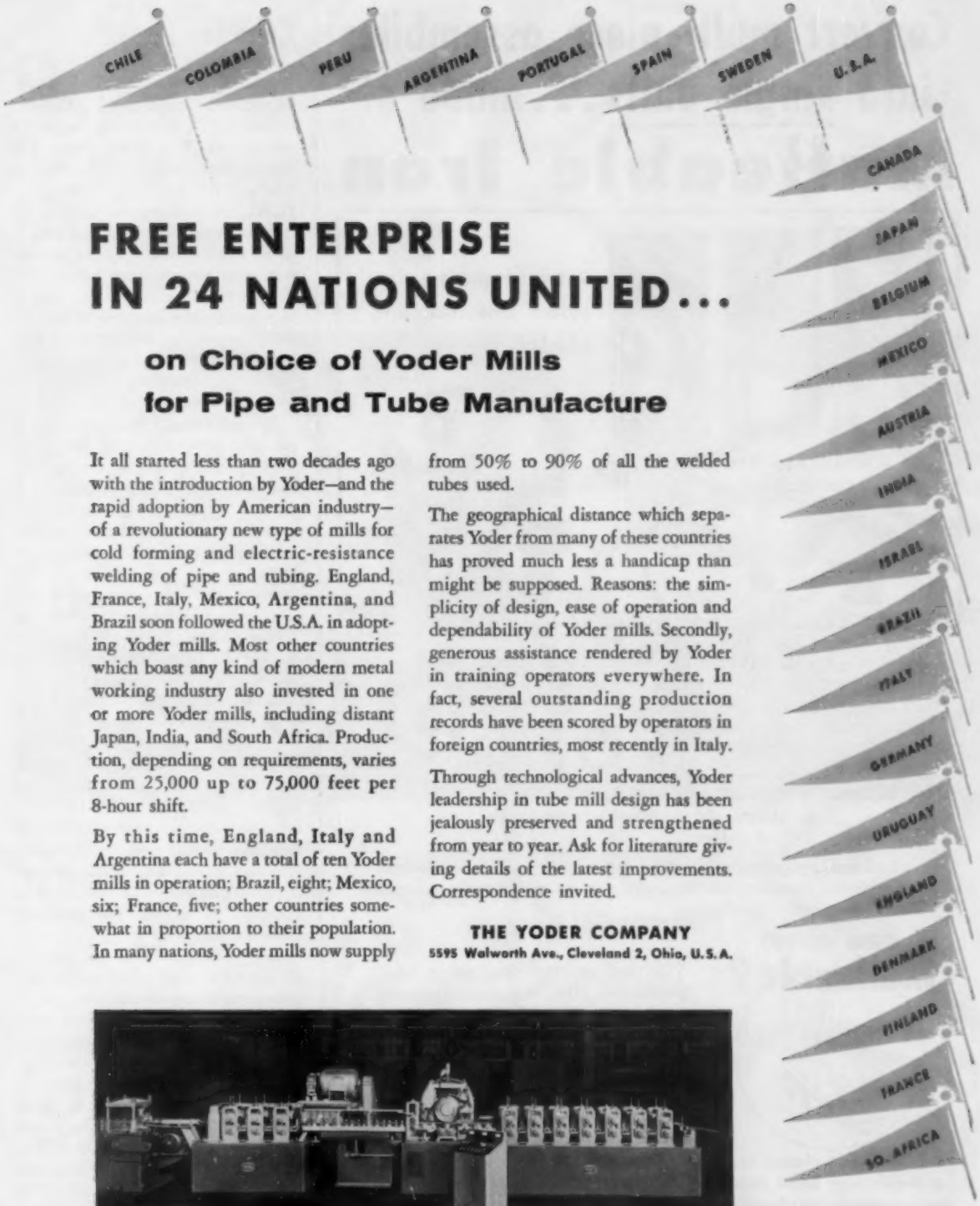
Corrosion of Cast Iron

Digest of "The Corrosion of Cast Iron", by R. I. Higgins, *Journal of Research and Development*, British Cast Iron Research Assoc., Vol. 6, February 1956, p. 165-177.

CORROSION RATES are most conveniently measured in terms of the depth of penetration below the original metal surface per unit of time, and expressed as mils (0.001 in.) per year. Many factors other than the composition of the metal and of the reacting liquid affect the rate, some of them being temperature, aeration, velocity of the liquid, and abrasion.

The corrosion resistance of unalloyed cast iron generally depends more on the soundness of the casting than on any feature of the composition or microstructure. Gray iron corroding in water usually becomes covered with a rust held in place by graphite, phosphide and carbonaceous residue from pearlite. With white irons this surface residue is more dense and tenacious.

Unalloyed cast iron is corroded rapidly, at rates often over 1 in. per yr., by HCl or other dilute mineral acids stronger than 0.001 *N* (0.001 g. equivalent per liter). But since $FeSO_4$ is insoluble in H_2SO_4 of over 65% concentration at room temperature, the corrosion rate in such acid is down to 5 mils per yr. At tem-



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By this time, England, Italy and Argentina each have a total of ten Yoder mills in operation; Brazil, eight; Mexico, six; France, five; other countries somewhat in proportion to their population. In many nations, Yoder mills now supply from 50% to 90% of all the welded tubes used.

The geographical distance which separates Yoder from many of these countries has proved much less a handicap than might be supposed. Reasons: the simplicity of design, ease of operation and dependability of Yoder mills. Secondly, generous assistance rendered by Yoder in training operators everywhere. In fact, several outstanding production records have been scored by operators in foreign countries, most recently in Italy.

Through technological advances, Yoder leadership in tube mill design has been jealously preserved and strengthened from year to year. Ask for literature giving details of the latest improvements. Correspondence invited.

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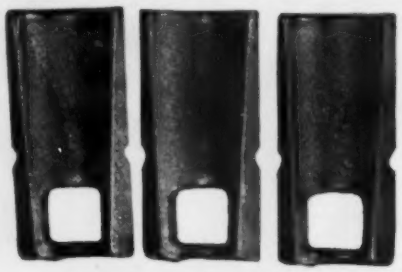

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Corrosion . . .

peratures above 85° F., however, corrosion is more rapid. Concentrated H_3PO_4 containing As, and a mixture of 60% HNO_3 plus 10% H_2So_4, can also be held safely in cast iron, but not strong HNO_3, pure H_3PO_4, or most organic acids.

The corrosion rate of cast iron in alkali solution below 70% in concentration at temperatures below 175° F. is under 8 mils per yr., but in stronger boiling solutions it may be 100 mils per yr. Molten NaOH may attack cast iron as fast as 800 mils per yr., but cast iron pots are often used for fused NaOH nevertheless.

Solutions of salts that hydrolyze to produce acid, such as $AlCl_3$, $Al_2(SO_4)_3$, $CaCl_2$, $FeCl_3$, $CuCl_2$, corrode cast iron rapidly especially if aerated. Chromates, nitrites, nitrates and permanganates in neutral solutions may, however, prevent corrosion of cast iron. Although ammonium salts are more corrosive than alkali salts, free ammonia reduces the corrosion rate.

The rate of corrosion in pure sea water is about 10 mils per yr., and in most fresh water the corrosion is usually slower. In the atmosphere, even with SO_2 pollution at 70% humidity, the corrosion rate is usually less than 5 mils per yr. so that exposed castings need not be painted. Well-drained open soils are not corrosive to cast iron, but in heavy wet clay pitting may occur at rates up to 40 mils per yr. High electrical conductivity of the soil generally indicates corrosivity.

Low alloy additions in general do not have much effect on the corrosion resistance of cast iron, but 3 to 5% Ni improves the resistance to alkalis, and 0.5 to 1% Cu may help in resisting slightly acid waters or crude oil containing sulphur.

The iron called Ni-Resist contains 20 or 22% Ni or Ni plus Cu, and is attacked very slowly by 20% H_2SO_4 below 70° F. At higher temperatures or concentrations the attack by dilute H_2SO_4 is rapid. Ni-Resist also resists 1% HCl up to 70° F., but not strong HCl or HNO_3. In 50% H_3PO_4 at 70° F. the corrosion rate is only 5 mils per yr. In dilute organic acids the corrosion rates are slower than for unalloyed iron; for example, corrosion rates are only 10 to 30 mils per yr. in fatty acid

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Corrosion . . .

stills at 445° F. instead of 200 to 800 mils per yr. for gray iron.

Alkalis attack Ni-Resist more slowly than plain iron, the rate for 70% concentration at the boiling point being not over 8 mils per yr., and for fused NaOH, 260 mils.

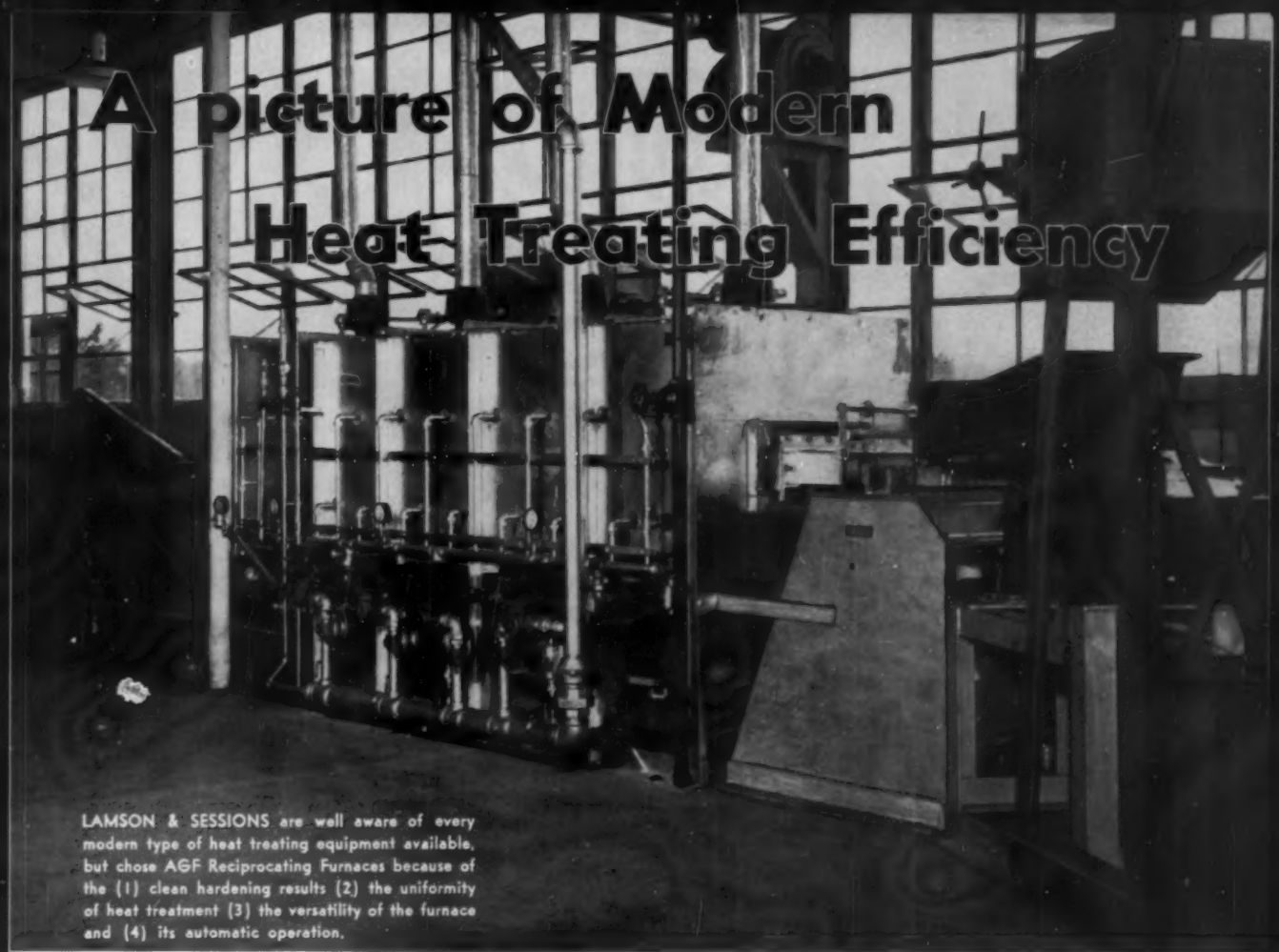
In most cold neutral salt solutions Ni-Resist has five times the resistance of ordinary cast iron. Dilute citrate, thiocyanate and hypochlorite solutions can sometimes be handled without excessive corrosion in Ni-Resist, but not in plain iron. In slightly salty or acid waters at high velocity, Ni-Resist is less corrosive than plain cast iron.

Cast iron containing 14.5% or more Si is hard and brittle like stoneware, and on exposure to H_2SO_4, HNO_3 or H_3PO_4 iron is removed from the surface and a protective SiO_2 coating is formed. In boiling H_2SO_4 the maximum corosion rate is 10 mils per yr. at 30% concentration; in boiling HNO_3 it is 40 mils per yr. at 3%, decreasing to 4 mils per yr. at 50%; in cold H_3PO_4 the maximum rate is 5 mils per yr., but on boiling the attack will be serious. HCl attacks this type of iron more rapidly, the rate exceeding 5 mils per yr. in 1% acid above 175° F., and in 40% acid above 32° F. With Si in the iron raised to 18% or with 3% Mo added, the rate can be held to 5 mils per yr. in 40% acid at 70° F.

High-silicon iron resists organic acids very well, but is no better than ordinary cast iron in HF, H_2SO_3, or alkalis. In acid salt solutions the corrosion depends on the type of acid formed by hydrolysis.

The best high-chromium cast iron, containing about 30% Cr, 1.2% C, and 1 to 3% Si, under oxidizing conditions is well protected from corrosion. Its corrosion rate in boiling HNO_3 is less than 5 mils per yr. for concentrations up to 70%, but with high concentrations the rate is much faster. In H_3PO_4 the corrosion rate is not over 5 mils per yr. for concentrations up to 60% at temperatures up to boiling, and for 85% acid at 175° F.

In acetic acid of all strengths and temperatures the rate of corrosion of high-chromium iron is below 5 mils per yr. This is true also of 10% formic acid at 70° F., 100% formic acid at all temperatures up to boil-



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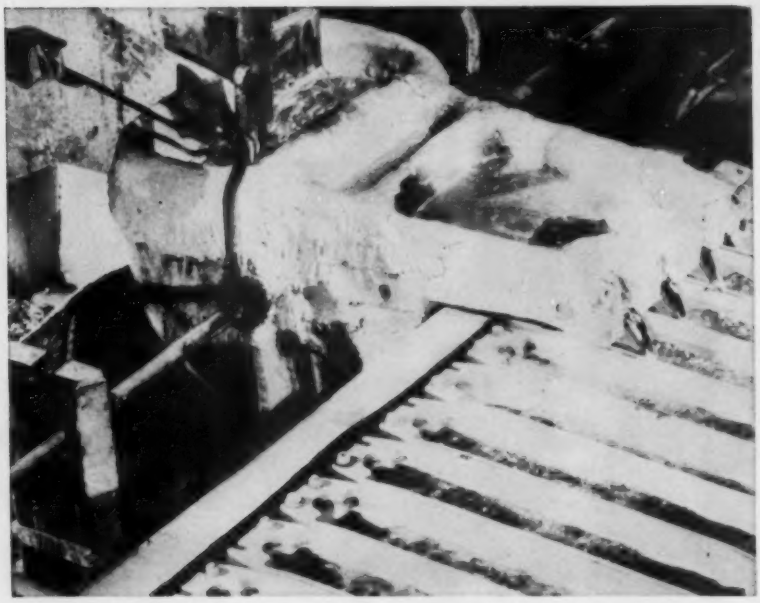

If you have had reason to doubt the performance capacity of certain aluminum alloys, it will pay you to consult Federated before you re-design or substitute another metal.

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Corrosion . . .

ing, boiling 1.5% lactic acid, and 28% citric acid at 212° F. In alkalis, however, corrosion is more rapid than that of plain cast iron. Sulphite liquors are resisted well; also solutions of $CaCl_2$, $ZnCl_2$, $Al_2(SO_4)_3$ (cold only), $(NH_4)_2SO_4$, and NH_4NO_3. Aerated sea water, mine waters, and many industrial acid waters do not corrode high-chromium iron, and it remains free from rust in the atmosphere when polished, or even as cast if its carbon content is below 2%.

GEORGE F. COMSTOCK

Liquid Metal Heat Transfer

Digest of "Review of Experimental Investigations of Liquid-Metal Heat Transfer", by B. Lubarsky and J. S. Kaufman, National Advisory Committee for Aeronautics, T. N. 3336, March 1955, 115 p.

INTEREST in the use of liquid metals as heat transfer media is becoming increasingly widespread. As a result, various investigators have conducted a number of theoretical and experimental investigations with regard to the heat transfer characteristics of liquid metals. When the Lewis Laboratory of the N.A.C.A. became interested in the problem, it was found that the results of different investigations were not always comparable due to differences in experimental conditions or methods of calculation. Typical of the differences were:

1. Liquid metal physical properties were used which differed from the currently accepted values.
2. Centerline temperatures, rather than mixed-mean temperatures, were used.
3. Some experiments were conducted with uniform heat input to the test section wall while other experiments approached constant wall temperatures.
4. Some investigators measured local fully developed heat-transfer coefficients while others measured average over-all coefficients.

Because of the number of differences in experimental approaches and the resulting differences in results, Lubarsky and Kaufman re-

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Liquid Metal . . .

evaluated the experimental data from 26 different investigations, using consistent assumptions and methods to permit better comparison of the experimental results and better comparison with theory. In this re-evaluation, all physical properties of liquid metals were taken from the second edition of the Liquid-Metals Handbook.

Even after re-evaluation, the experimental data for the Nusselt number for fully developed turbulent flow were found to have considerable spread. Most of the data were lower than predicted by theory. An empirical equation which best represents the heat transfer data for fully developed turbulent flow is

$$Nu = 0.625\ Pe^{0.4}$$

where Nu and Pe are the Nusselt and Peclet numbers, respectively.

From this re-evaluation, it was possible to draw the following additional conclusions:

1. The experimental results generally give higher values for heat transfer in the entrance region than predicted by theory.

2. The small amount of data on temperature distribution is in disagreement with theoretical predictions, with the discrepancy increasing as the Reynolds number decreases.

3. Experimental evidence is too limited to permit any conclusion with regard to liquid metal heat transfer characteristics in the laminar and transition flow regions.

C. O. SMITH

Titanium Carbide Produced by Infiltration

Digest of "Titanium-Carbide Products by the Infiltration Technique", by Leonard P. Skolnick and Claus G. Goetzel, A.S.T.M. Special Publication No. 174, 1956, p. 103-109.

NEW METAL-BONDED titanium carbide materials prepared by infiltration techniques have higher impact strengths than the conventional cemented carbides when tested either at room or elevated temperature. In addition these materials possess excellent stress-rupture properties. For example, at 1800° F. and 15,000 psi. some of them have

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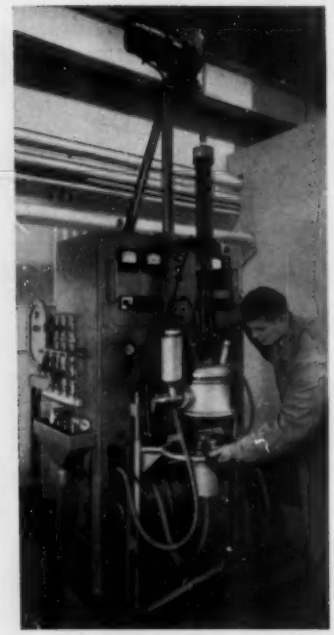

The Heraeus Vacuum Arc Melting Furnace Model VA-L200C, smallest of a line of Heraeus Furnaces sold by CEC.

With this new Heraeus Arc Melting Vacuum Furnace, the VA-L200C, you can get vacuum melts in "buttons" or ingots.

You can get them of Titanium, Zirconium, Tungsten, and other metals or alloys with high melting temperatures. You can get them fast and pure.

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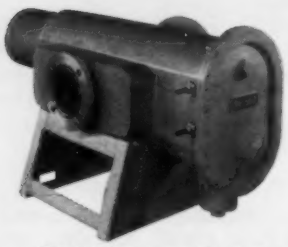
Fixed or consumable electrodes—You may use either fixed electrodes of tungsten or metallic carbides, or consumable electrodes of the metal you are melting.



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Titanium Carbide . . .

a stress-rupture life more than 1000 times that of X-40 which is one of the best of the conventional cast alloys for high-temperature service.

The materials are made by pressing titanium carbide powder at low pressures, sintering, and then infiltrating the voids with a high-strength, ductile, heat and corrosion resisting superalloy. This produces a fine isolated carbide phase in a continuous network of metal and provides improved toughness.

Impact strengths of cast X-40, cemented carbides, and infiltrated carbides are compared in the table. Tests were made in a "micro-Charpy" machine on unnotched bars, 0.187 in. square and 1.5 in. long. Figures represent in-lb. of energy absorbed in fracturing. It shows that infiltrated carbides have better impact strength than cemented carbides but are inferior to cast X-40, a metallic alloy. This deficiency may be overcome if the correlation between impact strength and microstructure can be determined. Control of the structure may be the route toward improved toughness.

Material	70 °F.	1800 °F.
X-40, as cast	40-50	<50
X-40, aged	30-40	<50
Cemented with Ni		
Ti (Cb,Ta)C	4.1-5.1	7.9-8.5
Ti (Cr)C	1.8-3.0	5.3-6.0
Cemented with Ni-Mo		
Ti (Cb,Ta)C	1.5-2.8	2.5-3.0
Infiltrated TiC		
No. TC-66-1	5.6-8.3	8.6-10.5
No SCA-100	10.5-14.5	17.5-23.5

The infiltration process has several basic advantages:

1. Low pressures can be used in the compacting dies. Complex shapes can be pressed, otherwise impossible with carbide powders. Low pressure also reduces die wear.
2. Infiltration can be done in a variety of ways dependent upon the type and density of the carbide skeleton and the infiltrant composition.
3. Close dimensional tolerances and excellent surface finishes can be achieved.

In the opinion of Messrs. Skolnick and Goetzel, the future of infiltrated titanium carbides looks very prom-

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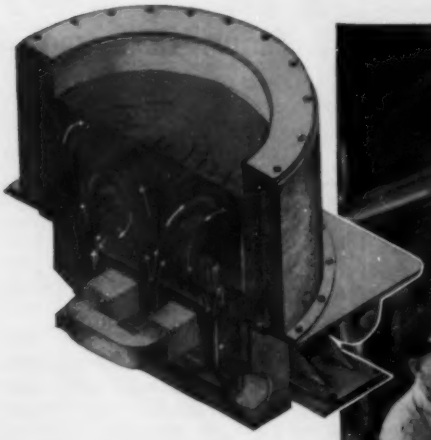
Brass and bronze foundries all over the country have found AJAX-TAMA-WYATT induction furnaces a reliable tool for melting silicon bronzes, aluminum bronzes, leaded bronzes, phosphor bronzes, and other high strength alloys. Operation is highly economical due to the good uniformity of the alloys, low ratio of rejects, drastic reduction of metal losses, and clean operating conditions. This recent development opens the field for the use of AJAX induction furnaces in all foundries where difficult-to-melt alloys are handled.



Cross section of AJAX-TAMA-WYATT twin coil induction furnace such as used at the Torrance Brass Foundry. Heat is produced within the molten metal in the secondary channels and conveyed throughout the melt by electromagnetic circulation, resulting in minimum metal losses and high uniformity of alloy. Temperature is automatically controlled.

(Photograph courtesy of Long Beach Press-Telegram, Long Beach, Calif.)

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The furnace pictured here is melting aluminum bronze at the *Torrance Brass Foundry, Torrance, Cal.*, operating at a temperature of 2400 F, for the production of high strength centrifugal castings. This unit is rated 100 kw. Note also the clean, smokeless operation as shown in the unretouched photograph.

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Courtesy of Cleveland Form Tool & Die Co.

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Titanium Carbide . . .

ising. Most molten alloys can be used as infiltrants; thus many grades of carbides can be formulated with interesting new properties. Components can be constructed by metallically bonding a pure metal to an infiltrated carbide. From results obtained to date, infiltrated titanium carbides may prove to be excellent materials for use at temperatures above 1600° F.

B. Trock

Vacuum Remelting of Superalloys

Digest of "Vacuum Remelting of Superalloys by the Consumable Electrode Process", by W. W. Dyrkacz, *Steel Horizons*, Vol. 17, No. 4, 1955, p. 1-4.

Numerous nickel-base and iron-base superalloys, hardened by additions of aluminum and titanium, were developed before and during the Korean War. Three alloys with relatively low strategic alloy content, the nickel-base alloys known as M-252 and Waspaloy and the iron-base alloy A-286, exhibited creep and stress-rupture strengths which were higher than the other materials then in use. This resulted in their being adopted commercially for turbine wheels, turbine blades, and high-temperature structural components.

These alloys could not be melted in air by conventional methods because their aluminum (1.3% max.) and titanium (2.5% max.) content resulted in poor cleanliness and workability which in turn caused numerous production problems. Induction vacuum melting proved to be one solution to these problems and this method was generally adopted. Another approach to the problem was vacuum melting utilizing the consumable electrode process.

The consumable electrode process is a double melting one. It utilizes electrodes which were cast from an electric furnace air melt of predetermined composition. These electrodes are then arc melted under vacuum in a water-cooled copper crucible to form ingots. The Allegheny Ludlum Steel Corp. is presently investigating this method and

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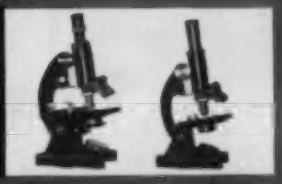

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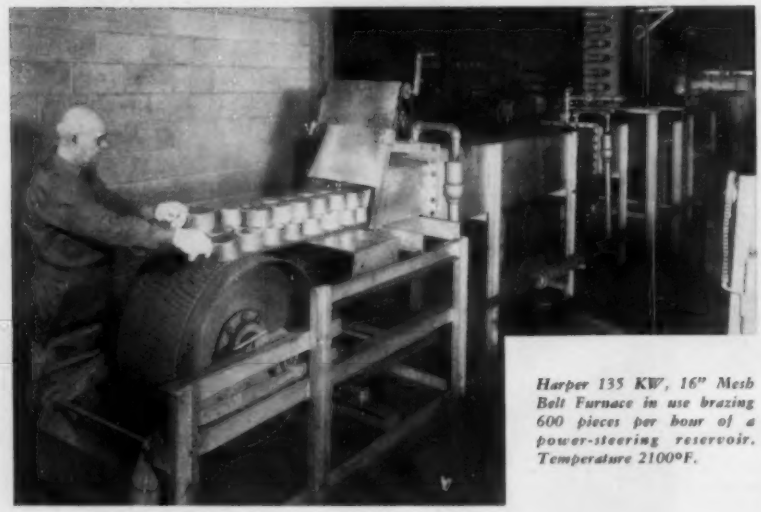

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Harper Mesh Belt Furnaces are available with or without alloy muffles. Matching preheat furnaces are also obtainable. For full information write for Bulletin 454 to Harper Electric Furnace Corporation, 40 River Street, Buffalo 2, New York.

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to date they have produced ingots up to 12 in. diameter and weighing 1000 lb. from the nickel-base superalloys, and up to 20 in. diameter and 5000 lb. from the iron-base alloy.

The superalloys produced by the consumable electrode vacuum process have been subjected to exhaustive tests. The results show that the process greatly improves the cleanliness, resulting in improved hot and cold workability. Furthermore, it reduces segregation in large billets and ingots of A-286. This is particularly important when fabricating gas turbine wheels which require high tensile ductilities in the center portion. This ductility is dependent upon the cleanliness and segregation of the center section of the large billets from which the wheels are made. The process also improved the hot tensile ductility, stress-rupture and hot fatigue strength of M-252 and A-286.

A comparison was made of superalloys prepared by conventional air melting methods and consumable electrode vacuum melting. Consumable electrode vacuum melting materials are superior in six respects: (*a*) greater cleanliness, (*b*) lower gas content (60 to 94% lower), (*c*) little or no segregation in large ingots or billets (*d*) more homogeneous composition, (*e*) improved workability and (*f*) improved high-temperature mechanical properties.

Percent decrease in gas content as compared to conventional air melting is as follows:

	WASPALLOY	M-252	A-286
H_2	88%	89%	79%
O_2	94	60	62
N_2	71	75	93

Another comparison of superalloys prepared by the consumable electrode process and the induction vacuum process failed to reveal any marked differences. Both methods produce a high-quality product but the adoption of either method should be based on the properties required in the end product and the economics involved. If ultra-high-purity materials are desired, it may be necessary to use both methods. casting the electrodes from an induction vacuum melt and remelting by the consumable electrode process. Both processes are still being studied.

B. TROCK

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Embrittlement of Tungsten by Ammonia

Digest of "The Embrittlement of Tungsten by Ammonia", by G. L. Davis, *Metallurgia*, Vol. 54, July 1956, p. 18-20.

TUNGSTEN oxidizes rapidly at temperatures above 1100° F., so it is processed and used at higher temperatures either in a vacuum or in protective atmospheres of inert or reducing gases. Pure nitrogen or hydrogen atmospheres are satisfactory but it is generally advantageous to use mixtures of the two gases. If the mixture of these gases contains traces of impurities such as oxygen, water vapor or carbon-containing gases, the heated tungsten wire will be severely embrittled.

During an investigation into brittle wires, it was discovered that small concentrations of ammonia gas could have a disastrous effect on the toughness of tungsten wires heated in a mixture of 90% nitrogen and 10% hydrogen. In view of the prevalence of nitrogen-hydrogen mixtures obtained from dissociated ammonia, it was considered that the subject warranted some study.

For the tests, a sample of commercial tungsten wire, 250μ in diameter, was used. It was heated by alternating current in a mixture of nitrogen with 10% hydrogen at atmospheric pressure. Ammonia was added to the mixture in controlled amounts. The embrittling effect was measured in terms of loss of tensile strength as measured on a standard wire testing machine.

At a constant temperature of 2190° F. and a constant time of treatment of 10 min., the tensile strength decreased with increasing ammonia concentrations. A graph of tensile strength versus the logarithm of ammonia concentration gave a straight-line relationship. When the embrittled wires were retreated at the same temperature and time in nitrogen-hydrogen atmosphere free from ammonia, brittleness was almost completely removed.

At a constant ammonia concentration of 0.2% by volume and a constant heating time of 10 min., embrittlement was found to occur over the range from 1100 to 3800° F., the maximum effect being in the region from 1450 to 1800° F.

Specimens of wire preheated at

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Embrittlement . . .

3600 and 4350° F., which produce complete primary and secondary recrystallization respectively, were heated in atmospheres containing 0.2% ammonia gas. The pretreatment at 3600° F. generally reduced the intensity of embrittlement. The pretreatment at 4350° F. completely prevented embrittlement by ammonia.

At a constant concentration of 0.2% by volume of ammonia and a temperature of 2200° F., there was a straight-line relationship between loss in strength and the logarithm of time, the loss in strength increasing with time. When wires were heated in pure active nitrogen and hydrogen, no embrittling effect was observed.

Wires were polished electrolytically before treatment in ammonia to ascertain whether the reaction was associated with the clean metal surface or with surface contaminants such as oxides and graphite. The embrittling action was almost completely eliminated by this treatment. Polished wires which were locally oxidized and treated in the presence of ammonia vapor became brittle. A control wire treated in the same way but with the atmosphere free from ammonia was not embrittled.

Wires treated in ammonia so that they became brittle had their ductility restored by electrolytically polishing the surface.

X-ray diffraction examination of the embrittled wires showed no distortion of the tungsten lattice, but a second phase resembling a nitride of tungsten was present. Microscopic examination indicated no second phase or change in microstructure of the test samples, and the fractures of embrittled specimens were transcrystalline.

The following conclusions seem justified:

1. The embrittling action seems to be due to reaction with ammonia rather than the products of its dissociation, and is associated with the presence of nitride as an insoluble phase.

2. The reaction seems to involve diffusion of some agent into the metal from the surface.

3. Either the reaction is initiated (or catalyzed) by oxide on the surface or the extent of the effect is

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Embrittlement . . .

strongly dependent on surface area.

4. The effect is not apparent with specimens which have undergone coarsening by secondary recrystallization.

5. Since the embrittlement is removed by dissolving off a disproportionately small quantity from the surface, this defective surface material must act as a source of ready initiation of cracks which then propagate through the unaffected interior of the specimen. Tungsten is, in fact, very notch sensitive.

From a practical point of view, it is imperative that traces of ammonia be excluded from atmospheres in which tungsten is heated, although the effects can be mitigated by certain pre or post treatments.

G. W. BROCK

Graphitization Rates in White Iron

Digest of "First Stage Graphitization in Iron-Carbon-Silicon Alloys", by W. S. Owen and J. Wilcock, *Journal* of the Iron and Steel Institute, Vol. 182, January 1956, p. 38-43.

THE NUCLEATION and rate of growth of graphite at temperatures from 1630 to 1830° F. was investigated in a pure white iron containing only 3.38% carbon and 1.13% silicon; the effects of manganese and sulphur on this reaction were thus eliminated. The annealing was carried out in the vacuum chamber of the dilatometer so that there was a direct correspondence between the dilatometric and microscopic results.

When white irons are heated for a longer time than is required to remove all cementite, the total number of graphite nodules per unit volume decreases progressively with time. Starting with a mixture of saturated austenite and cementite, it is obvious that several processes are taking placé simultaneously:

1. Initial nucleation of graphite in fine particles in saturated austenite.

2. Solution of carbon from cementite into the depleted austenite at the austenite-cementite interface.

3. Growth of nodules in size with time.

4. When all cementite has disap-

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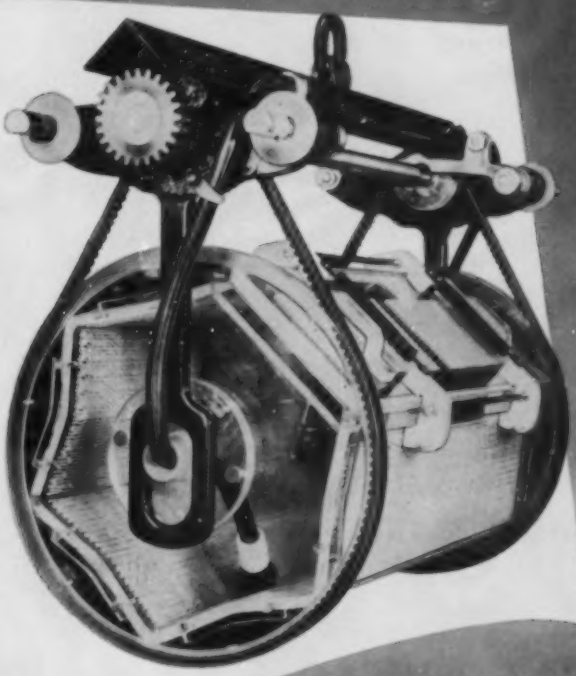

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Graphitization . . .

peared, a resolution of fine nodules in austenite and diffusion of the carbon to larger nodules.

When all of the cementite has disappeared, the austenite is just saturated in the vicinity of the smallest nodules. Since the interfacial energy per volume of graphite is greater for small nodules than for large, the growth of the large nodules takes place at the expense of the small.

The general features of nucleation are determined by the same environmental conditions as those which affect the growth. During the early part of the reaction, the rate-controlling mechanism is the transfer of carbon atoms across the graphite-austenite interface. The fact that increasingly more remote carbide particles start to dissolve before the nearer ones have disappeared suggests that the solution of cementite is a somewhat slower process than the growth of graphite. However, there is sufficient excess of cementite present during the early stages of the reaction to maintain the supply of carbon. It is not until the volume of cementite remaining is small that the cementite solution mechanism can start to exercise a control over the whole reaction. This control may be operative toward the end, but if it is, its effect is overshadowed by the re-solution of small graphite nodules.

E. C. WRIGHT

Aluminum-Copper-Cadmium Alloys

Digest of "Aluminum-Copper-Cadmium Alloys", by E. A. G. Liddiard and H. K. Hardy, *Metal Treatment and Drop Forging*, Vol. 23, February 1956, p. 67-71.

VERY SMALL ADDITIONS of indium, tin or cadmium enhance the age hardening properties of aluminum-copper alloys. Of these additions, only cadmium can be used in commercial alloys that may contain magnesium as an impurity. A recommended composition is: 4.8 to 5.4% Cu, 0.1 to 0.15% Cd, 0.25% Si, 0.3% Fe, 0.3 to 0.8% Mn, 0.2 to 0.12% Ti, 0.02 to 0.10% Mg, 0.005% Sn, 0.05% Pb, 0.05% Zn, 0.05% Ni,

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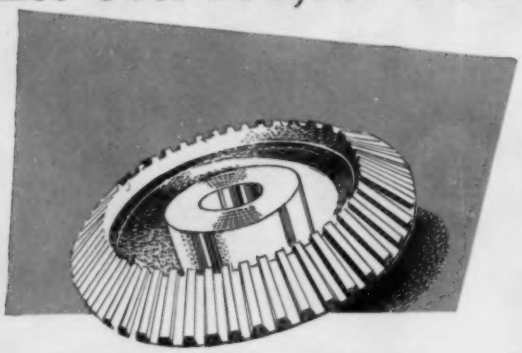
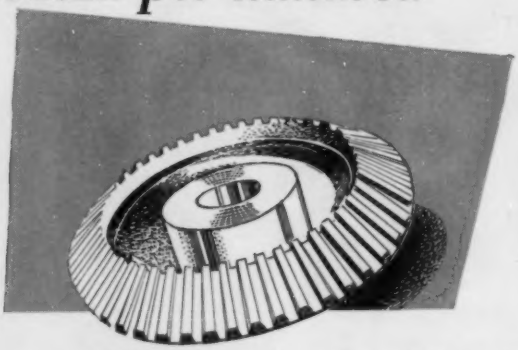


one costs $31.21 *per hundred*



and one costs $22.51 *per hundred*

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Elongation — 1%	Elongation — 2.5%
Rockwell Hardness — C34	Rockwell Hardness — C26
Apparent Density — 7.78	Apparent Density — 6.83
Production Steps — Nine	Production Steps — Four

*(7½% addition of 50% chrome/ 50% nickel, plus 1% carbon)

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Al-Cu-Cd Alloys . . .

0.02% Cr, with the remainder being aluminum.

The copper can be increased if the silicon does not exceed 0.15%. The cadmium should be added to the melt shortly before pouring. During or after the cadmium addition, the melt temperature should not exceed 1345° F. at any time to avoid loss of cadmium by volatilization.

Annealed at temperatures from 825 to 915° F., the tensile strength of an Al-Cu-Cd alloy containing 4.9 Cu and 0.10 Cd ranged from 5700 to 2800 psi. with elongations of 55 to 58%. In the interval between 930 and 985° F., the strength continued to decrease (to 2200 psi.), while the elongation after this treatment was well over 90%. The high ductility after annealing at temperatures above 930° F. suggests that the alloy can be forged directly from a cast bar. This was done with chill cast billets made in the laboratory. Forging is said to be easier than with any other high-strength aluminum alloy.

Depending upon the dimensions of the specimen, extrusion speeds varying from 25 to 40 ft. per min. could be attained on sections whose wall thickness varied from 0.050 to 4 in. In all cases the maximum speed was from two to three times that attainable with B.S. L-65 alloy (4.2 Cu, 0.7 Mg, 0.7 Si, 0.6 Mn) under the same conditions. Recommended conditions for extrusion were: soak at 840 to 880° F. for 6 to 8 hr.; extrusion temperature 805 to 840° F.; container temperature 715 to 735° F. A marked drop in properties was noted on any cold work performed on the alloy between solution heat treating and aging treatment.

Annealing experiments showed that the new alloy became softest after annealing at 660° F., but that it was effectively softened after treatment at any temperature between 480 and 930° F. Flash annealing for short times at relatively high temperatures was permissible. Hot rolling at 895° F. produced some edge cracking. All operations of the hot rolling and of the tube drawing were carried out with schedules identical to those used for B.S. L-71 alloy (4.4 Cu, 0.7 Mg,

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Al-Cu-Cd Alloys . . .

0.7 Si, 0.6 Mn). The new alloy is clad without difficulty, but the copper content makes diffusion into the cladding likely unless the final solution heat treatment time is kept at a minimum.

Solution annealing treatment at 985° F. for 6 to 8 hr. is recommended for castings. For thin sheet, the time may be reduced to 15 min. This should be followed by artificial aging at temperatures not above 365° F. Cold reduction of 5 to 10% between solution annealing and aging appears to destroy the effect of the cadmium addition. The mechanism of this effect has not been determined.

Interestingly, sheets of a 4.25 and of a 5% copper alloy containing cadmium, solution heat treated and aged for 6 hr. at 365° F., or 16 hr. at 330° F., were not subject to stress-corrosion when loaded as cantilever beams with stresses up to 49,000 psi. and sprayed daily with a 3% sodium chloride solution. Similar alloys without cadmium failed at all stresses over 15,500 psi. However, the cadmium-containing material is subject to stress-corrosion if not fully aged (3 hr. at 430° F.).

Little work has been done on castings, but it is known that cadmium additions to both a 4.5% copper alloy and to a 3% Cu, 5% Si alloy accelerate their response to age hardening.

Mechanical properties of specimens cut from a large forging of aluminum-copper alloy (5.4 Cu, 0.09 Cd, 0.67 Si, 0.57 Fe, 0.50 Mn, balance Al) in longitudinal position are: proof stress 57,800 psi., ultimate tensile strength 71,900 psi., elongation 9.9%. Properties of test pieces cut from a similar forging of the high-strength alloy D.T.D. 683 (5.5 Zn, 2.5 Mg, 0.5 to 1.5 Cu, balance Al) with the test pieces in the longitudinal position are: proof stress 66,300 psi., ultimate tensile strength 72,600 psi., and elongation 13.7%.

The ease of fabrication of the aluminum-copper-cadmium alloy is stressed in the paper. This ease of fabrication can make possible higher production rates and hence reduced costs, or the production of more intricate forgings.

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The Ultrasonic Impact Grinder

Digest of "Ultrasonic Impact Grinding", by Patrick J. Duran, A.S.M.E. Preprint No. 56-SA-47, June 17, 1956, 10 p.

COMBINATION of an old metalworking principle with a new method of application has resulted in an entirely new technique for the accurate shaping of impressions in metallic and ceramic materials. The old concept is that power transferred from a soft metal punch through a hard abrsasive will form cavities in materials which are harder than the tool tip. The new phase is the introduction of ultrasonic vibration of the punch and tool. Practical result: ultrasonic impact grinding.

Built in the form of a complete machine after some years of experimentation, the system employs an electromechanical transducer to convert a-c. power into mechanical motion. Current is supplied at high frequency (25,000 cycles per sec.). Vibrations of the transducer are amplified and transmitted by a shaped tool cone to an attached cutting tool. The latter vibrates in a plane always parallel to the axis of the cone. When an abrasive slurry is introduced between the cutting tool and the material to be worked, the cutting tool actually "drives" the abrasive into the workpiece, thereby reproducing its own counterpart in the piece.

Action of the transducer derives from the magnetostrictive properties of the metal in its core. By this is meant the phenomenon of the metal stretching and contracting when placed in a varying magnetic field, the metal contracting minutely as the field strength increases.

Amplitude of vibration at the base of the tool is relatively small with large forces, but the reverse is desired at the tool tip. The inner transmitting cone and the tool cone provide this transformation and might be likened to mechanical transformers. For a given amount of energy at the frequency in use, amplitude is a function of the cross-sectional area—the smaller the area the higher the amplification.

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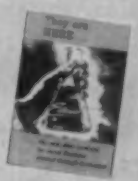

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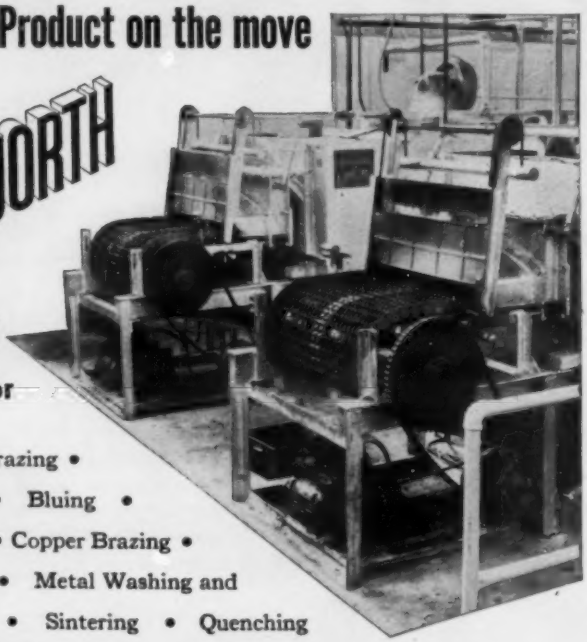

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Ultrasonic Grinder . . .

able and will vary in contour with the job to be handled and the tool size and shape.

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In operation, a tool which is the male counterpart of the impression to be cut is fixed to the end of the tool cone. The tool may be ordinary mild steel or even softer metal such as copper or lead.

While the tool vibrates at 25,000 cycles per sec., an abrasive slurry is flowed between the tool and the work. A small space filled with abrasive fluid develops between the vibrating tool face and the workpiece. Small particles of abrasive (200 to 800 grit size depending upon finish desired) are accelerated by the ultrasonic motion of the tool tip and are driven with tremendous impact against the work, thus chipping or grinding an exact replica of the tool face into the work. This is the action identified as impact grinding. The work is fed up to the tool to maintain constant grinding force between the two.

Grinding force seldom exceeds 10 lb. This, plus the absence of tool-work contact and the presence of a cool abrasive means that the action is one of "cold cutting". Work is not stressed or distorted and does not increase in temperature. Also, it is not normally necessary to clamp the work since the tool does not wander.

Depending upon the material being worked, the practical grinding area of the tool face will vary from 1.1 sq. in. for boron carbide, for example, up to 3.1 sq. in. for ferrite, glass or germanium. Average grinding rate with a ½-in. diameter tool ½ in. deep, by actual tests, ranges from 0.007 in. per min. for toolsteel and 0.009 in. per min. for tungsten carbide, on up to 0.075 in. per min. for germanium and 0.100 in. per min. for glass. Ratio of stock removal to

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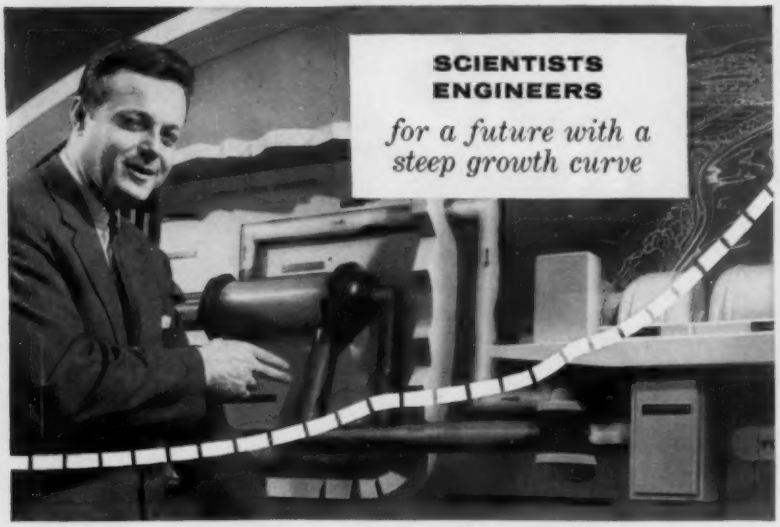
Ultrasonic Grinder . . .

tool wear covers a wide area, figuring 250:1 for ceramic materials, 200:1 for germanium, down to 1:1 for toolsteel and carbides. However, because there is little lateral cutting action, the exact profile of the tool is maintained as it wears. Beyond that, tools can be replaced at moderate cost.

Here are a few typical applications of the process, with the time required for the operation: Cutting 0.004 in. slots ⅝ in. long in a 0.050-in. thick stainless steel hydraulic valve—10 min.; sizing S-shaped wire drawing dies in carbide—15 min.; cutting a small carbide stamping or embossing tool 0.025 in. deep—2 min., sinking a complete blanking die of intricate shape in hardened toolsteel to a tolerance of 0.002 in.—45 min.; simultaneously cutting a dozen holes accurately in ceramic spacers—a few seconds; dicing several hundred germanium diodes at one time—less than 1 min.

Research is continuing on higher power machine units which will handle larger cutting areas at faster speeds.

ARTHUR H. ALLEN



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Minimizing Grinding Stresses

Digest of "Influence of Grinding Fluids Upon Residual Stresses in Hardened Steel", by H. R. Letner, A.S.M.E. Paper No. 55A-123, November 1955.

GRINDING FLUIDS are used for cooling, to prevent thermal stressing of the abrasive wheel bond and irregular cutting depth in the metal and to reduce friction and keep metal particles from adhering to the wheel (lubrication). Since either of these functions may affect the plastic deformation of a metal's surface, the residual stresses induced by grinding may also be influenced by the grinding fluid.

The effects of grinding in air, water containing $NaNO_2$ rust inhibitor, water-oil-soap mixtures (soluble oils), and various grinding oils on the residual stresses in steel were recently compared at Mellon Institute in Pittsburgh. The steel was a 1% carbon, chromium-vanadium ball bearing steel in the form of 3 by 0.16-in. square bars, which had been annealed, oil quenched and tempered C-59 hard. Heat treating stresses were removed by grinding off 0.01 in. from each side of the specimen; stresses in deeper regions were considered insignificant.

Test grinding was done with a 46-grit fused-alumina wheel having a vitrified bond. The wheel was 0.75 by 1.25 in. in size and was mounted on a surface grinder with a horizontal spindle. Peripheral speed was 6000 ft. per min., with traverse speed of 60 ft. per min., cross feed of 0.05 in. per traverse, and down feed of 0.001 in. per cut to 0.10 in. total. The grinding fluids were fed as usual to the wheel periphery in amounts sufficient to cover the work surface. Their compositions are tabulated in detail in the document, and the residual stresses for 13 different specimens to depths up to 0.01 in. are reported graphically. The maximum in every

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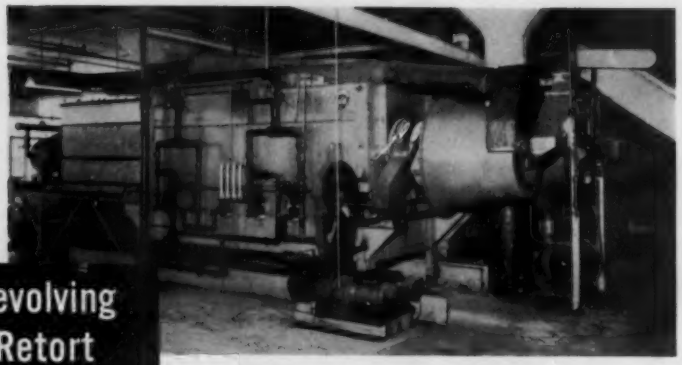

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Grinding Stresses . . .

curve, usually around 120,000 psi. in tension, occurs at about 0.001 in. from the surface and falls to zero about 0.006 in. below the surface.

The use of water containing 0.5% nitrite rust inhibitor gave about the same internal stresses as grinding in air, and with 10% inhibitor the stresses were a little higher. With the soluble oils, some specimens showed comprehensive stresses 0.000,05 in. below the original surface, but at about 0.001 in. depth the tensile stresses were all of the same order of magnitude as with the 10% rust-inhibitor solution. With the straight grinding oils, the stresses at depths up to 0.000,05 in. were always compressive, and one of these oils (with a very high content of sulphochlorinated fats and about 3.5% sulphur) gave a maximum residual tensile stress of only 60,000 psi. instead of 100,000 psi. or more.

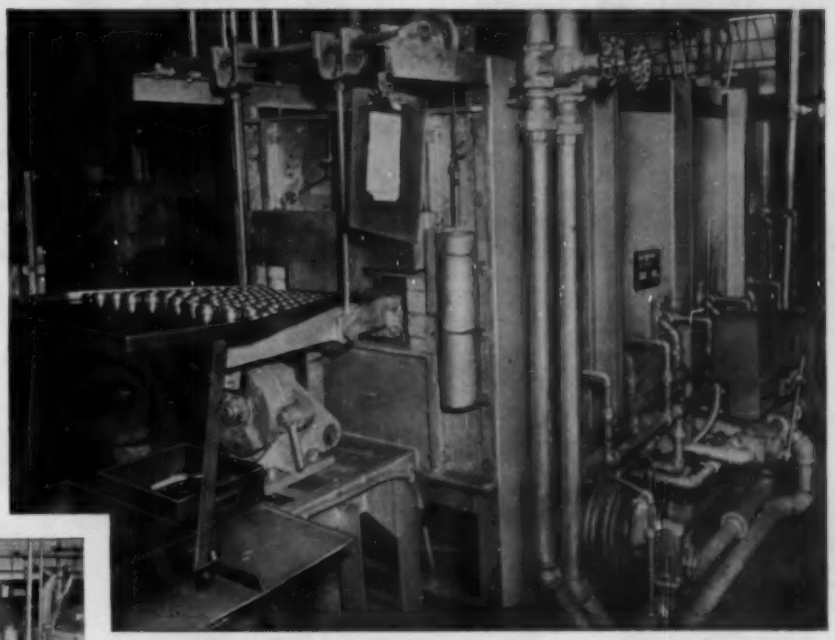
Although solutions of rust inhibitor or soluble oil seem to show no advantage in these tests over air as a grinding fluid, the cooling effect of the liquid was probably helpful in minimizing local temperature variations. The straight grinding oils (compressive stresses were found at the surface when using them) were definitely advantageous because such compressive stresses are beneficial to the service life of most mechanical parts. The oils with the high fat contents seemed to produce more desirable stress distributions, but further study is needed for precise correlation of the oil composition with the residual stresses in steel ground with the oils.

The heat capacity of the grinding fluid evidently has little effect on the residual stresses induced by grinding. The beneficial effect on the residual stresses of the oil with high sulphochlorinated fat content must therefore be due to a reduction in thermal and mechanical stresses, and in the amount of heat generated during chip formation. Other work has shown that certain gas atmospheres, without much ability to carry off heat, likewise reduce friction in machining, and improve the surface finish.

Lubrication by a grinding fluid is thus more important than the cooling effect.

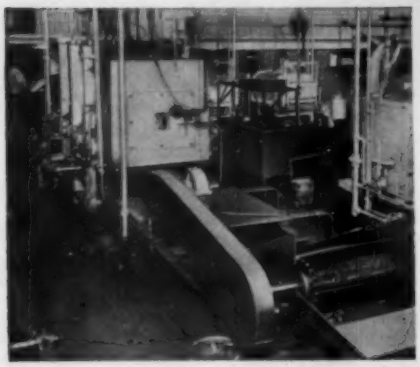
GEORGE F. COMSTOCK

Lesson in low heat-hour cost at NORMA-HOFFMANN



(1) Charge end of Stewart Reciprocating Hearth Furnace showing bearing races entering. Average output is 125 pounds per hour. S.A.E. 52100 steel is hardened to 65-66 Rockwell C. Nichrome hearth casting has been operating over 9 years.

(2) At discharge end, ball races are dropped into conveyer tank and quenched from 1540–1550 degrees.



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Evaluating the Impact Strength of Cermets

Digest of "Cermets and the Problem of Impact Strength", by Frank W. Glaser and N. Grossman, *Powder Metallurgy Bulletin*, Vol. 7, April 1956, p. 90-93.

MANY CERMETS having satisfactory high strength at high temperatures have been developed, but the designer is still very hesitant in using these materials. Lack of ductility and poor impact strength are their more important shortcomings. The authors believe that the traditional methods of evaluating these properties in metals and alloys should be somewhat modified for the cermets. In their experiments, results were obtained on a systematic series of TiC-base cermets containing a Ni-Cr-Co binder (60% Ni, 20% Cr, 20% Co). The amount of binder varied from 25 to 65% by weight. The size effect was also investigated by varying the cross section of the specimen from 0.0225 to 0.156 sq.in.

The standard Charpy impact test yielded erratic data because the energy absorbed was very small. The modified Charpy test, calibrated in in-lb., gave more reproducible results, but the most important uncertainty in this type of testing came from the unknown energy imparted to the flying fragments of the specimen. The N.A.C.A. drop test was also evaluated and the authors believe that in this test the impacting velocity is unrealistically small. The fourth testing method consisted of impacting the specimen with a bullet of constant mass (mass not given in the paper) and with velocities ranging from 6380 to 18,800 cm. per sec.

The authors claim that this test method closely simulates the conditions encountered in jet engines. Consistent results were apparently obtained by measuring the velocity at which no visible damage occured to the specimen. A definite specimen size effect was observed in all these tests and the impact strength seemed to increase with increasing specimen size. The ratio of binder material to hard carbide phase had a very important effect on impact strength. The decrease of impact strength with decreasing amount of binder was particularly severe below 45 to 50% binder material.

In discussing the results of these experiments, the authors express the opinion that the future of cermets for many high-temperature applications, such as gas turbine blades, is severely hampered by the designer's requirements of a high impact strength. In their opinion, the impact strength criterion is overemphasized and a new approach to the problem may be required. Ballistic tests applied to specimens having the shape of the particular part under consideration seem to be more realistic than impact tests on standard shape specimens. The authors also believe that a better understanding of the effect of the binder phase may lead to better resistance to fragmentation of cermets. Progress has been made in obtaining a very thin film of binder material on individual particles of hard metals, and this appears to be a very promising approach to the problem of "ductile" cermets.

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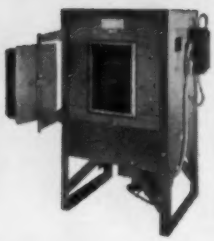

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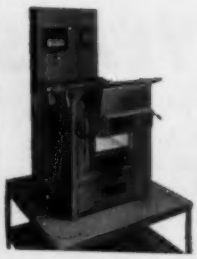

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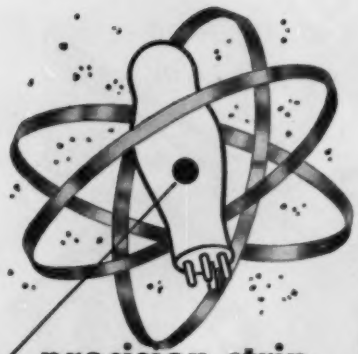

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Brittle Structures

Digest of 1955 Adams Lecture before the American Welding Society, given by L. Grover, and entitled "An Interpretation of Research and Experience in Structural Welding", *Welding Journal*, Vol. 35, March 1956, p. 209-224.

THE AUTHOR of the document under review, L. Grover, is chairman of the Structural Steel Research Committee and the Fatigue Testing Committee of the Welding Research Council, and consequently his summary of the brittle fracture problem in structural welding should be of particular interest to bridge and structural engineers.

The existence of a "transition" temperature (or even two "transition" temperatures), as defined by sudden changes in the result of impact tests at progressively lower temperatures, has no meaning unless a quantitative correlation can be shown to exist between such a transition temperature and the performance of the full-scale structure. This correlation has now been made for ship plate steel, following extensive work by Pellini and his associates at the Naval Research Laboratory. The present author briefly presents their findings, in which the "nil ductility temperature" (NDT) is associated with the initiation of a brittle fracture, while the "fracture transition, elastic" (FTE) is associated with the highest temperature at which propagation of brittle fracture is still possible. The separation of the brittle fracture problem into these two stages – namely, of initiation and of propagation – is by now a well-accepted idea.

More experimental investigation is badly needed into the relationship between Charpy V-notch data (or other laboratory tests) and the behavior of structures. One of these investigations is described and discussed in detail. It involved drop hammer tests on full-scale wide-flange beams, cooled to subatmospheric temperatures. This work was done at Columbia University under Prof. Krefeld for the Structural Steel Research Committee. A comparison of the transition temperatures for unwelded beams and Charpy V-notch specimens is shown by the tabulation on p. 214.

Other investigators check the

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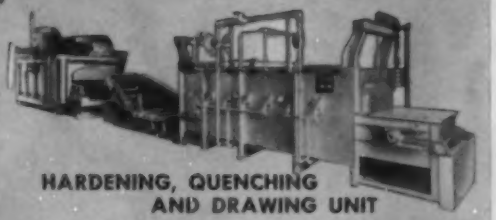

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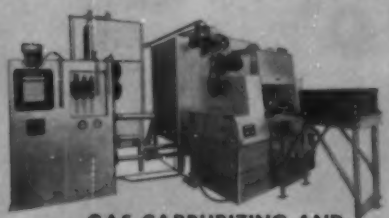

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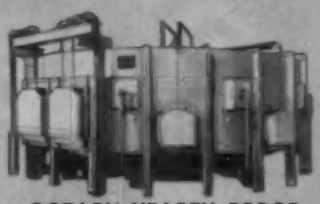

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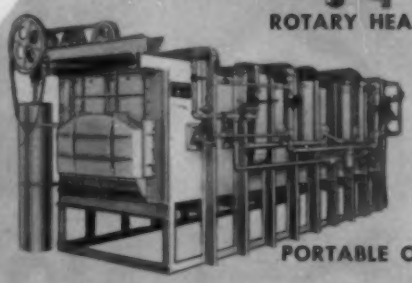

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Brittle Structures . . .

results on welded beams tested at Columbia University, and show that the role of welding in the development of brittle fracture enters through its effect on the base material, particularly in the heat affected zone where the microcracks developed during the welding operation may initiate fracture. Fractures can be made to follow the welded joint only when the notch toughness of the base metal is greatly superior to that of the weld metal.

Another experimental investigation which helps the structural engineer to understand and control brittle fractures in full-scale structures was carried on by Feely and co-workers at the Esso Research Laboratories and described in *Welding Journal* in February 1954 and December 1955.

These studies on crack propagation in steel plates, including those conforming to A.S.T.M. Specification A-7, are the only omission the present reviewer feels should have been included in Mr. Grover's report.

Many other brittle failures of structures, with an emphasis on welded bridges, are reviewed. Included in this list is the spectacular collapse of the Three Rivers Bridge in Quebec during January 1951 and service failures of riveted as well as welded structures. The factors discussed include such items as fabrication operation, effect of strain rate, effect of acuity of notch, effect of temperature upon the yield stress, effect of oxygen cutting or of shearing or punching.

The author concludes that "the excellent service records of a good many welded bridges serving in very cold climates indicate that the NDT of the steels pegs the lowest safe operating temperature at an unduly conservative figure for bridges". New structural materials such as A-131 (ship steel) and A-373 (structural steel for welding) assure better uniformity of notch toughness as compared with the older A-7 specification; they seem to be well worth the small additional cost when put into outdoor structures subjected to low temperature.

F. Forscher

Comparison of Transition Temperatures

	Fully Killed Steel	Semikilled Steel
Plain unwelded beams with machined, coped holes and sharp pressed notch	+25° F.	+85° F.*
Plain unwelded beams with web holes made by flame-cutting	−30	−60 to −115
15 ft-lb. level, Charpy V-notch specimens	−42 to −45	+25 to +33

*Approximately the lowest temperature at which failure will occur by buckling rather than by propagation of a small tear or crack.

Cold Roll Forming

Digest of "Cold Roll-Forming and Manipulation of Light-Gauge Sections", by E. Griffin, *Journal* of the Institute of Metals, Vol. 84, March 1956, p. 181-197.

The process of cold roll forming lends itself readily to present day requirements of high productivity, close quality control, and economy in labor and material. The basic raw material, cold rolled strip produced on continuous mills, excels all ferrous and nonferrous products produced by other methods in uniformity of thickness, consistency of properties, and surface conditions.

Basically, cold roll forming can be described as a process in which a flat strip of metal is progressively formed into a desired shape by passing through several stands of rolls arranged in tandem. Each pair of forming rolls does its particular part in developing the section shape. Thus the number of stands required to produce a given shape will depend on the intricacies of that shape and also on the type and gage of strip material used. Generally speaking, the most complicated of shapes

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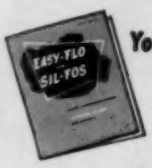

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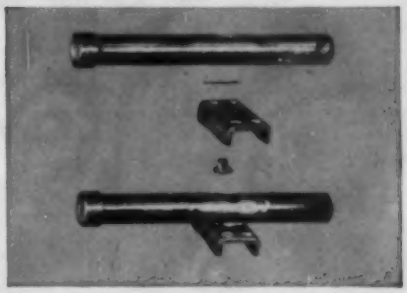
One of the beauties of silver alloy brazing is that it can join a wide variety of metals with the same excellent results and at remarkably low cost. Whatever you are making of metal, whether joints are involved *or not*, it will pay you to investigate EASY-FLO brazing. We will be glad to explain the benefits of simplified design made possible by modern silver brazing techniques —and how these advantages can be profitably applied to your production requirements. Just call us.



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Roll Forming . . .

can be produced on roll-forming machines having no more than 12 stands or stages.

The strip materials used in the manufacture of cold roll-formed sections are supplied in coils and include aluminum and its alloys, low-carbon mild steels, low-alloy steels, stainless steels, copper, brass, phosphor bronze and zinc. On simple shapes the output per day, per machine, allowing for unavoidable interruptions, is in excess of 30,000 ft. with only one operator.

A cold roll-forming machine normally consists of three basic units, a decoiling drum or cradle, a roll-forming unit, and a device for cutting to specific lengths. The capacities of machines are generally classified according to the maximum width of strip and the gage of material which can be roll formed.

The actual horsepower required to roll form strips into a section profile depends on many variable factors. Theoretical values for work done in forming, based on assumptions and confirmed by experimental results, give values that are only 10% of the actual power required in practice. This means that 90% of the power used is needed to overcome certain unavoidable factors. Foremost among these sources of power loss are friction on the strip during forming, flattening of the strip between the bending points, cold work on the strip due to variation in the gage above the nominal standard, friction between the mating surfaces of the forming rolls, and the mechanism of the roll-forming machine. Typical calculations of power requirements for cold forming are given, including comparative data on power requirements for cold forming on hydraulically operated vertical presses and for cold roll forming.

Tooling for the production of cold roll-formed sections can be very costly. Except for standard shapes, such as channels, angles and in some instances, box channels, hat and Z-sections, the rolls must be manufactured specifically to produce the desired shape, and as each stage represents a particular part in the forming of the section, no two stages are identical. Furthermore there is a minimum production quantity below which the manufacture of cold roll-formed sections becomes prohibitively expensive. This minimum production figure for a normal section is in the region of 3000 to 5000 ft. Once the tools have been produced, however, their forming potential is far beyond that of any other method of producing cold formed sections. Normal commercial tolerances on cold roll-formed sections are $\pm$ 0.010 in. with a straightness factor of L/300. For aircraft sections these tolerances are reduced to $\pm$ 0.005 in. and L/600 for straightness.

Because of the complexity of many forming operations the manufacture of the forming rolls requires a high degree of skill. Attempts have been made to mass-produce forming rolls on automatic lathes, but this method has not met with any great success, due mainly to variations in the shape of every roll produced. Automatic lathes with tracer movements can and do produce these shapes, but due to the high capital expenditure, the old way (using templets) is more economical.

Generally, high speed steel cutting tools are most suitable for machining rolls, although carbide-tipped tools may be used on the high-carbon high-chromium rolls.

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Roll Forming . . .

is generally carried out under strict supervision and in accordance with material suppliers' instructions. Mild steel rolls are case hardened to a depth of 0.025 in. by the cyanide process. Meehanite cast iron forming rolls are oil quenched and tempered, as are the high-carbon high-chromium steel forming rolls. The finished hardness of the roll surface is Rockwell C-56.

The strip material is fed through an edge guide so placed as to center the strip accurately in the first stand of the forming rolls. Lubrication during roll forming is of primary importance. For steel strip a light machine oil is used, but when forming aluminum alloy a mixture of paraffin wax and lanolin has proved very successful.

It is an established fact that for all types of materials more consistent results are obtained when the strip undergoes severe forming operations. For example, complicated shapes are obviously more difficult to produce, but once the forming rolls have been adjusted a more uniform section can be obtained than when the material is subjected to forming operations which impose only a small amount of plastic deformation. Section profiles having wide, flat surfaces are also very difficult to produce. In such lightly formed sections any deformation of the strip surface due to unwinding from the coil, heat treatment before forming, or defects occurring during manufacture of strip will be apparent on the final section. Procedures for avoiding or minimizing such defects are given.

Supplementary discussions of cold forming on press brakes, and manipulation of cold roll-formed sections, by bending, press working, swaging, together with information on cleaning and finishing of cold roll-formed parts, are also included in the paper.

W. W. AUSTIN

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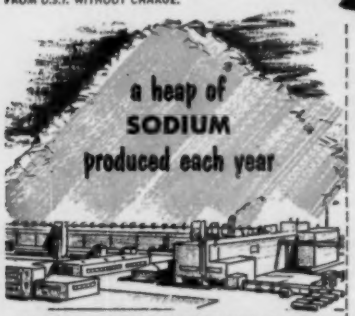

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Significance of Fatigue in Pressure Vessel Design

Digest of "Significance of Fatigue Data in Design of Pressure Vessels", by Thomas J. Dolan, *Welding Journal*, Vol. 35, May 1956, p. 255s-260s.

THE A.S.M.E. and joint A.P.I.-A.S.M.E. codes are based on static loading conditions and reflect years of practical experience. One major factor not covered by codes is the rational procedure for design and fabrication where fatigue failures may occur. The purpose of this article is to point out some of the difficulties inherent in the interpretation of fatigue data for inclusion in design procedures and to indicate why careful consideration must be given to the possibilities of fatigue failure in vessels subject to repeated loadings.

High-strength materials and improved methods of calculating localized stresses have led to a demand for reappraisal of codes and modification to allow increased design stresses. Currently empirical code formulas result in local yielding under hydrostatic tests. Under static loading this is safe but high localized stresses and secondary bending stresses exceeding the yield point would cause progressive failure after a large number of repetitions of loading. The major uncertainty for many vessels operating at room or slightly higher temperature is resistance to fatigue. Bridges, marine vessels and similar structures have been known to experience catastrophic fatigue failure. Obviously,

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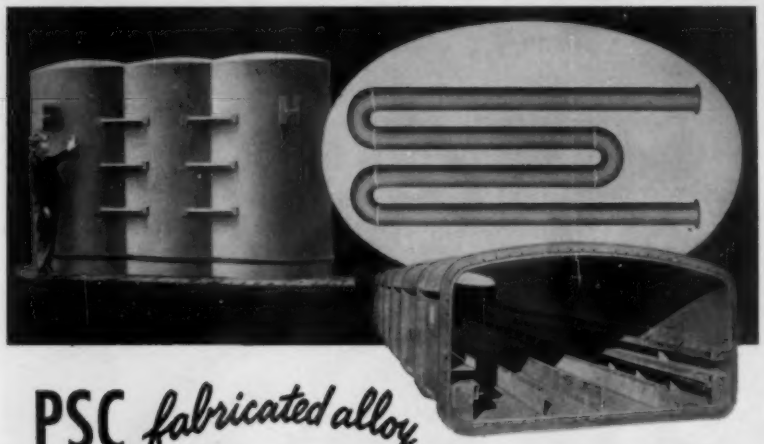

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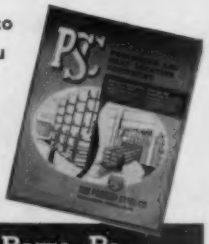

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Fatigue . . .

pressure vessels subject to repetitious loading must make allowance for progressive fracture in both design and fabrication. This is particularly true where increased life, frequent large variations in operating pressure or temperature, and a trend toward greater working stresses are expected.

For fatigue conditions, damage accumulates during each cycle of loading and develops at localized regions of high stress; it finally causes visible cracks to grow, join and spread. Invariably, progressive fracture is initiated by a stress-raiser -- an abrupt step or recess in the surface, such as a drum head, bracket or pipe connection. Minor discontinuities may lead to drastic reduction in fatigue strength. It is not uncommon to have fatigue strength cut in half by poor design details.

Stress-raisers cannot be avoided entirely. Progressive failure can begin at them even though nominal stresses calculated by the usual formulas are well below the static strength of the metal. In general, a vessel safe from the viewpoint of static load design would have adequate resistance to fatigue fracture if all severe stress-raisers were eliminanted. For fatigue conditions, the localized stresses at abrupt changes of section, such as a head junction, are the significant stresses that cannot be readily computed. By proper attention to design details it is frequently possible to lower the range of peak stresses developed. A small decrease will give a large increase in fatigue life. Thus, if the maximum stresses are controlled by eliminating severe stress-raisers, adequate fatigue life can be obtained.

Laboratory data should be regarded as qualitative only since fatigue strength of forged or hot rolled members is only a small fraction of that of ground or polished specimens. In addition, the "size effect" further reduces fatigue strength. Furthermore, the same metal tested in two different machines may give different results and it is not unusual to have supposedly identical samples give fatigue results varying by a factor of 10 to 1. In short, the fatigue strength of individual pressure vessels may be lower than that

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Fatigue . . .

predicted on the basis of small-scale laboratory tests of specimens or carefully prepared models.

Any vessel safe at room temperature will be safe at lower temperatures because fatigue strength of steel increases as temperature drops. At higher temperatures (above 700° F.) fatigue strength drops drastically and creep becomes the primary consideration. The effect of stress-raisers at high temperature is comparable to that at room temperature. Creep may reduce local stress peaks but does not reduce the range of stresses applied in service. Corrosion, erosion, and chemical attack drastically reduce fatigue strength. If stress-raisers and corrosion both are present the damaging effects are even greater. Rolled plate having a pitted surface or laminations should be regarded as exceedingly harmful from the viewpoint of fatigue. Arc strikes and underbead cracking also are sources of fatigue failure. It is estimated that these defects reduce fatigue strength by 30%.

Any design for fatigue resistance must rely on better and more complete analysis of peak stresses at discontinuities. While fatigue resistance tends to increase with the static strength of steel, the relationship is not a linear one. Therefore, there is a limit to what may be expected by changing to higher tensile strength steels. It should be possible to avoid fatigue failure in most classes of pressure vessels by the use of fatigue data from studies that closely simulate service conditions, by eliminating bad design details, by better methods of stress analysis and by adequate inspection to insure against defective material and poor workmanship.

H. J. NICHOLS

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Metallurgical Problems in Nuclear Power

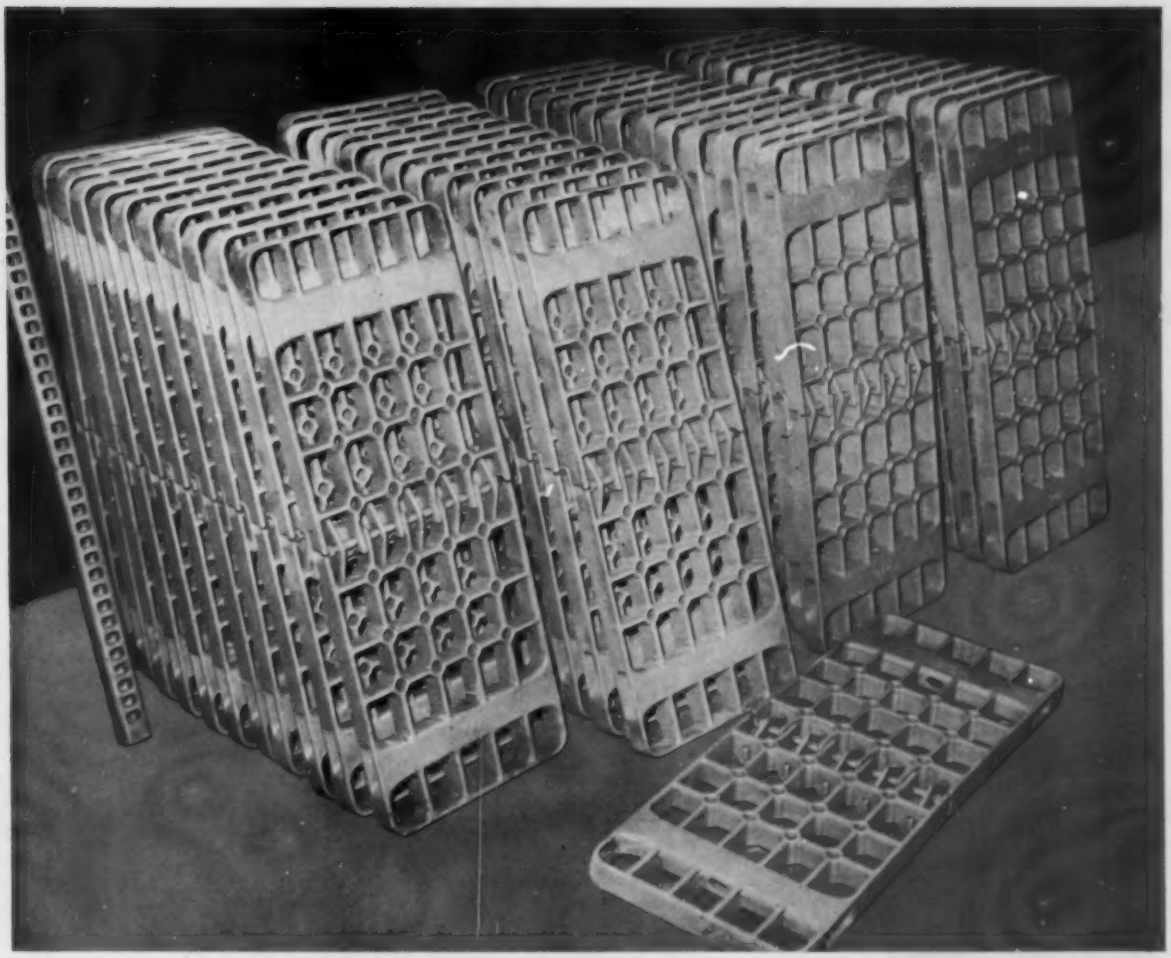
Digest of "Metallurgical Research in Nuclear Power Production", by J. G. Ball, *Journal* of the Institute of Metals, Vol. 84, March 1956, p. 239-250.

THE UNIQUE SERVICE conditions and the unusual materials which must be used serve to differentiate nuclear metallurgy from any other branch of metallurgical endeavor. Regardless of the specific type of nuclear reactor, the associated metallurgical problems can be considered under the general headings discussed below.

Irradiation Stability

Several broad effects are generally associated with fission. These are: (*a*) formation of interstitialcies and vacancies by neutron bombardment and collision by fission fragments, (*b*) internal stress systems, possibly accompanied by plastic deformation due to intense local heating around the fission fragment track, and (*c*) an increase in the number of atoms present with a tendency to a decrease in density.

The effect of the fission spike in uranium is to lead to anisotropic



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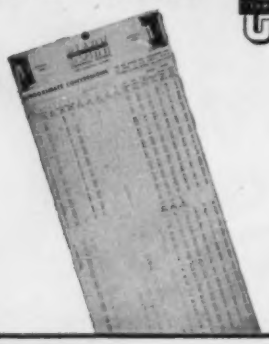

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Nuclear Power . . .

deformation which ultimately causes wrinkling on the previously smooth surface in a randomly oriented polycrystalline aggregate or growth of the sample with marked texture. These effects can be reduced by use of a randomly-oriented fine-grain material. This can best be achieved by β-quenching. The decrease in density (swelling) appears to be due to the fission-product inert gases. Attempts have been made, rather unsuccessfully, to eliminate this by using loose-sintered powder compacts with a high degree of interconnected porosity. Mechanical inhibition of swelling by a sufficiently strong can is feasible but only with an increased loss of neutrons. Dispersion of fuel in a nonfissile matrix is also feasible but requires a matrix of low absorption cross section. Ceramics may be more stable under irradiation than metals but have a tendency to become brittle and thus susceptible to failure under thermal stressing. Nuclear poisoning can be reduced and swelling eliminated by using liquid fuels but these introduce other problems which are covered below.

Thermal Stability

Thermal instability of fuel elements within a reactor arises from several sources: (*a*) chemical or diffusion interaction between fuel and cladding, (*b*) mechanical interaction between fuel and cladding on repeated thermal cycling, (*c*) repeated thermal cycling of the fuel, and (*d*) thermal stresses caused by temperature gradients.

Although barrier layers, such as uranium-aluminum, have been effective in preventing reaction between fuel and cladding, this causes considerable temperature drop at the interface which is not acceptable for reactors with high power ratings. Ample opportunity exists for research into solid-state reactions between uranium and possible cladding materials. The difference in thermal coefficient of expansion gives rise to "thermal ratcheting" under thermal cycling. One solution is the use of a very strong can which is impractical because of excessive thickness. A more practical solution is a metallurgical bond between fuel and cladding, but such bond

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Class 10. Results by unconventional techniques (other than electron micrographs).
Class 11. Slags, inclusions, refractories, cermets and aggregates.
Class 12. Color prints in any of the above classes. (No transparencies accepted.)

AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which, in the opinion of the judges, closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $100, will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters in Cleveland.

All photographs may be retained by the Society for one year and placed in a traveling exhibit to the various Chapters. They will be returned to the owners in May 1958 if so desired.

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Nuclear Power . . .

properties are not fully understood.

Cladding Materials — Aluminum has been extensively used because of low absorption cross section, ready availability and comparative ease of fabrication. For higher temperatures other materials must be considered. The required special properties of high-temperature strength and compatibility with coolant and fuel require the investigation of such elements as columbium, zirconium and beryllium. Each of these presents problems in extraction, alloying for improved creep strength and ductility, and fabrication. The Zr-Sn, Zr-Al and Zr-Mo systems merit additional investigation for creep properties. Present results favor the Zr-Sn and Zr-Al systems. Beryllium is very desirable from the nuclear viewpoint but has very low ductility at room temperature, a problem for which no solution has yet been found. The major problems with beryllium appear to be related to large-scale production and economical fabrication. The toxicity problem further complicates the picture.

Corrosion

Corrosive action occurs in aqueous, gaseous, liquid metal and fused salt media. The use of zirconium for reasons of neutron economy, where stainless steel would have satisfied the corrosion requirements, has spurred research into consumable arc methods of melting and alloying, with much effort still required. Another major problem still unsolved is the "breakaway" corrosion of zirconium, in which the attack rates suddenly increase after a relatively inert period of a few hours to hundreds of days. Much additional work, with considerable emphasis on "in-pile" experiments, is required. Aluminum-nickel alloys are being investigated as possible replacements for zirconium in pressurized water reactors.

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Height comparison chart for model WP-3 P&H Welding Positioner

Mfr.	Minimum	Maximum	Range
P&H	46¼"	82¼"	36"
"A"	34½"	54½"	20"
"B"	42"	66"	24"
"C"	40"	55"	15"

The chart on the left clearly shows how a typical P&H Welding Positioner has a 50% greater elevation—can turn larger weldments and lift them almost 1½ feet higher than competitive makes.

Welding is easier, faster, with a P&H Positioner. Table tilt is clear through 135° — without legs or posts to interfere with rotation.

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Nuclear Power . . .

ily a problem in "mass transfer" in which the metal being corroded is dissolved in the liquid metal in the high-temperature portion of the circuit and precipitated out in the low-temperature portion. This mass transfer by solubility changes can be minimized by promoting stable intermetallic compounds between liquid and solid. For instance, addition of zirconium to a dilute solution of uranium in bismuth inhibits mass transfer by the formation of zirconium nitride on the surface of steel structural components.

Fabrication — Although most of the nuclear metallurgy research is devoted to fabrication, many problems are more of a development than research nature. All possible techniques are dominated by the high reactivity of the metals involved. Much work is being done with integral cladding, in which the fuel and cladding are completely bonded together, eliminating welding. Powder metallurgy methods offer both flexibility and excellence but the high reactivity of the materials, combined with the large powder surface areas, requires meticulous control. Direct extrusion of powders at high temperatures has given good quality solid metal. This method has been extended to produce structures otherwise unobtainable — for example, the uranium to uranium-carbide cermet.

Alloys and Physical Properties

The complex electronic structures of the refractory metals, zirconium, columbium, and molybdenum and the fuel metals, thorium, uranium and plutonium can be expected to give different behavior than the simple metals such as sodium and copper or even the transitional metals such as the iron group. Work is being conducted on solid solutions of zirconium, columbium and molybdenum in δ - U, both on solubility limits and magnetic susceptibilities, in the hope of developing a theory explaining the solution behavior and to determine the low-temperature electronic specific heats.

The available evidence indicates that there is a very delicate balance between the alternative electronic arrangements possible for elements in the neighborhood of uranium and plutonium, so that a given metal may show different valences according to circumstances, such as its atomic environment in the alloy, chemical compound, or even allotropic form. The physical behavior of plutonium is particularly complex with six allotropic modifications, one of which has a negative thermal coefficient of expansion. Several explanations have been suggested for this and experimental work is continuing in an effort to provide full explanation.

Additional work is being done in diffusion studies which may lead to a partial explanation of "swelling". Neutron diffraction techniques are being used to determine the atomic positions in an alloy of neighboring transition elements and in magnetic moment studies. A relatively novel field of alloy study is in slurry fuels and blankets. Slurries can be made by cooling an alloy from the liquid to a temperature between the liquidus and solidus or by suspending insoluble particles in a liquid. Possible useful metallic slurry systems are Pb-U, Bi-U and Bi-Th. Studies of the effect of temperature change with the accompanying changes in particle size, shape and distribution and their effect on pile operation are being intensified.

C. O. SMITH

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Subsidiary of U. S. Automatic Corp.
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March 25 through 29, 1957

TOP AUTHORITIES ARE INSTRUCTORS

Some of the subjects to be discussed—

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- **USES AND DESIGN CRITERIA IN AIRFRAMES AND MISSILES**
  S. R. Carpenter, Convair, San Diego, and T. Mociun, North American Aviation, Inc.
- **CIVILIAN APPLICATIONS**
  L. J. Barron, E. I. du Pont de Nemours
- **TITANIUM FASTENERS**
  Harry Brenner, Olympic Screw and Rivet Co., and J. A. Van Hamersveld, Northrop Aircraft, Inc.
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  Battelle Memorial Institute
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  Harry Schwartzbart, Armour Research Foundation
- **SOURCES AND INFLUENCE OF IMPURITIES**
  D. H. Barbour, Electro Metallurgical Company
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  Army-Navy Applications
  Jet Engine Applications
  Cleaning Titanium
  Forming of Extrusions
  Cutting, Milling, Drilling, and Chem-milling
  Powder Metallurgy
  Economics of Using Titanium
  Resistance Welding

Metals men who need better knowledge of titanium alloys—men who really *want* to get ahead in this new and promising field—cannot afford to miss the TITANIUM CONFERENCE! Through its Metals Engineering Institute, the American Society for Metals is conducting a five-day conference on present day problems in the *Titanium* field at Los Angeles, March 25 through March 29, 1957. This is a unique opportunity to get the latest information on titanium. Registration fee of $125 for the entire course covers daily lunches and study materials, which include the new ASM Titanium Course.

BRING YOUR THINKING UP TO DATE

There's still a lot that you can learn about titanium. The lectures offered at this conference, coupled with the exchange of ideas at three panel discussions will help to bring *your* problems into focus. Examine the topics at the left, and you will be convinced that the TITANUM CONFERENCE will help you modernize your thinking and improve your understanding of mechanical working, fabrication techniques, and new alloys, some of which have not yet reached the production stage.

LET'S TAKE ACTION

You should know what's going on in your field when it comes to titanium. Top men in the field will present informal lectures at the conference. Your next move should be clear—place your registration in the mail WITHOUT DELAY, or send for full information AT ONCE. Use convenient coupon.

TITANIUM CONFERENCE **March 25-29, 1957**

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Detroit's high-speed automobile body presses are busier than ever turning out body components for today's modern-design cars. More intricate door and fender sections of the new models demand a steel of the highest quality that can take the required deeper draws in its stride. Without question, that steel is Youngstown Cold Rolled Sheets and Strip—the best available anywhere.

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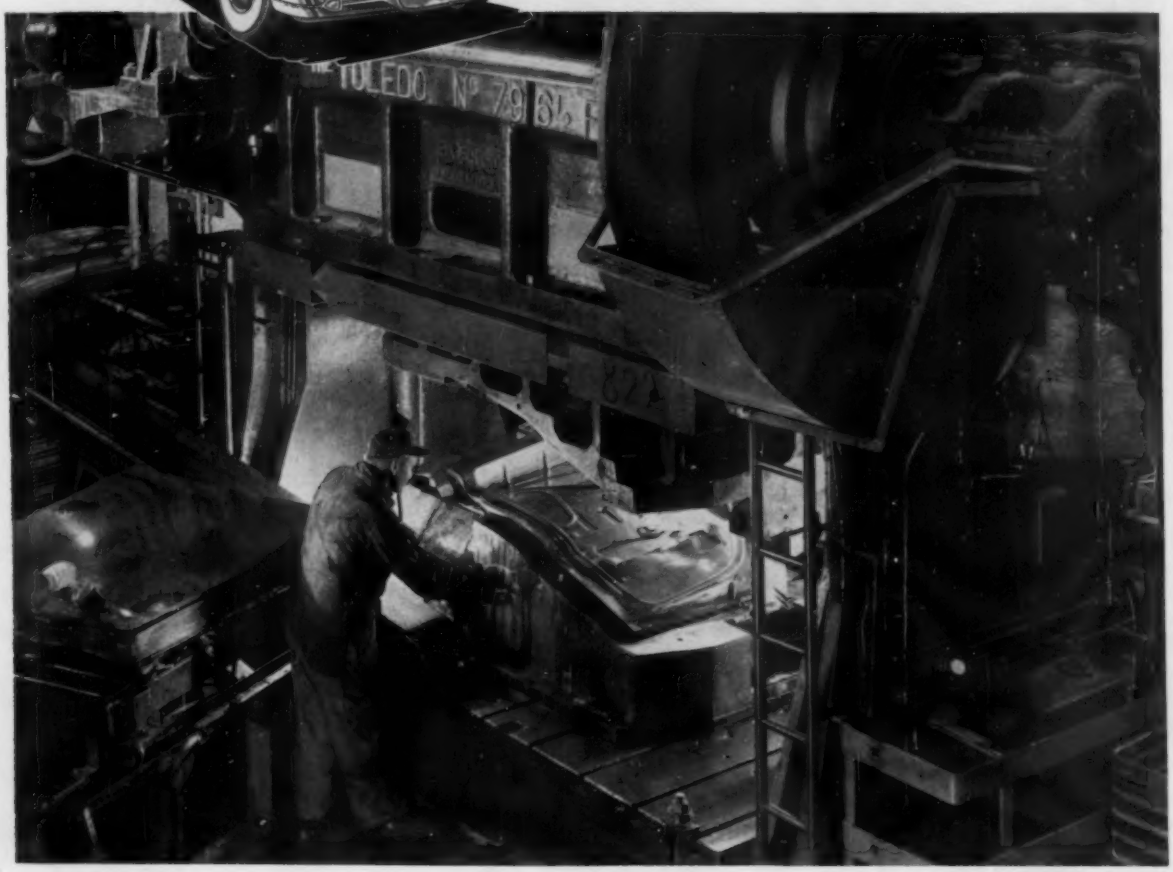

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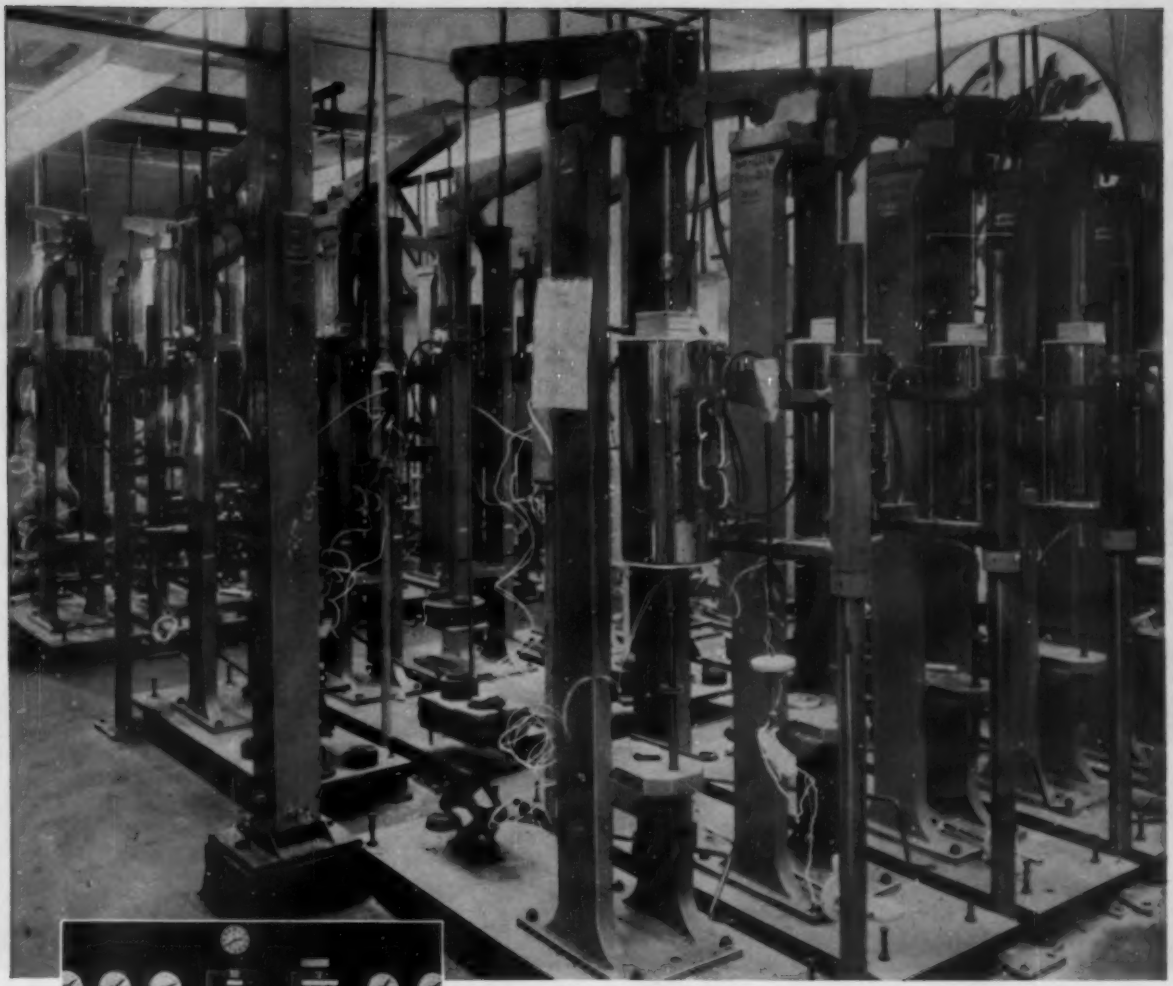

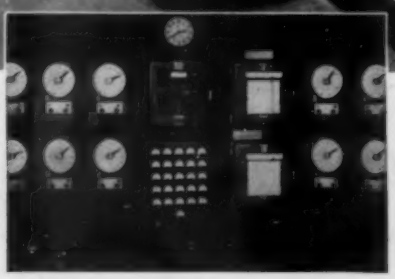

41 Speedomax® H Controllers Reduce Overshoot . . . Speed Recovery on Creep Rupture Machines

Here are only some of the creep rupture machines and Speedomax controllers at Wyman-Gordon, Worcester, Mass. To meet government specs for jet plane forgings made of titanium and special alloy steels, Wyman-Gordon has installed 2 banks of creep rupture testing furnaces with space-saving Speedomax H proportioning control. This combination assures them of quality control on a production basis . . . permits them to turn out part after part which will meet the stresses induced in jet propelled aircraft.

To keep production moving, Speedomax H D.A.T. control enables operators to bring furnaces up to temperature in minimum time. Rate of approach, in most cases, eliminates overshoot . . . speeds recovery time after sample change. By continuously regulating heat input in proportion to furnace needs, this Speedomax H control holds temperature of furnaces within ±2 F and in addition, eliminates the need for manually readjusting auto transformers.

Additional instrumentation includes four multiple-point Speedomax G recorders for each bank of furnaces, and 80-point and 76-point Model D Speedomax G indicators for checking furnace temperatures at any time from a central location.

Why not investigate Speedomax H when installing your next heat treating furnace—whether it's electric or fuel-fired, continuous or batch. A phone call or letter to your nearest L&N office —or to 4927 Stenton Ave., Phila. 44, Pa.—will bring you more information.

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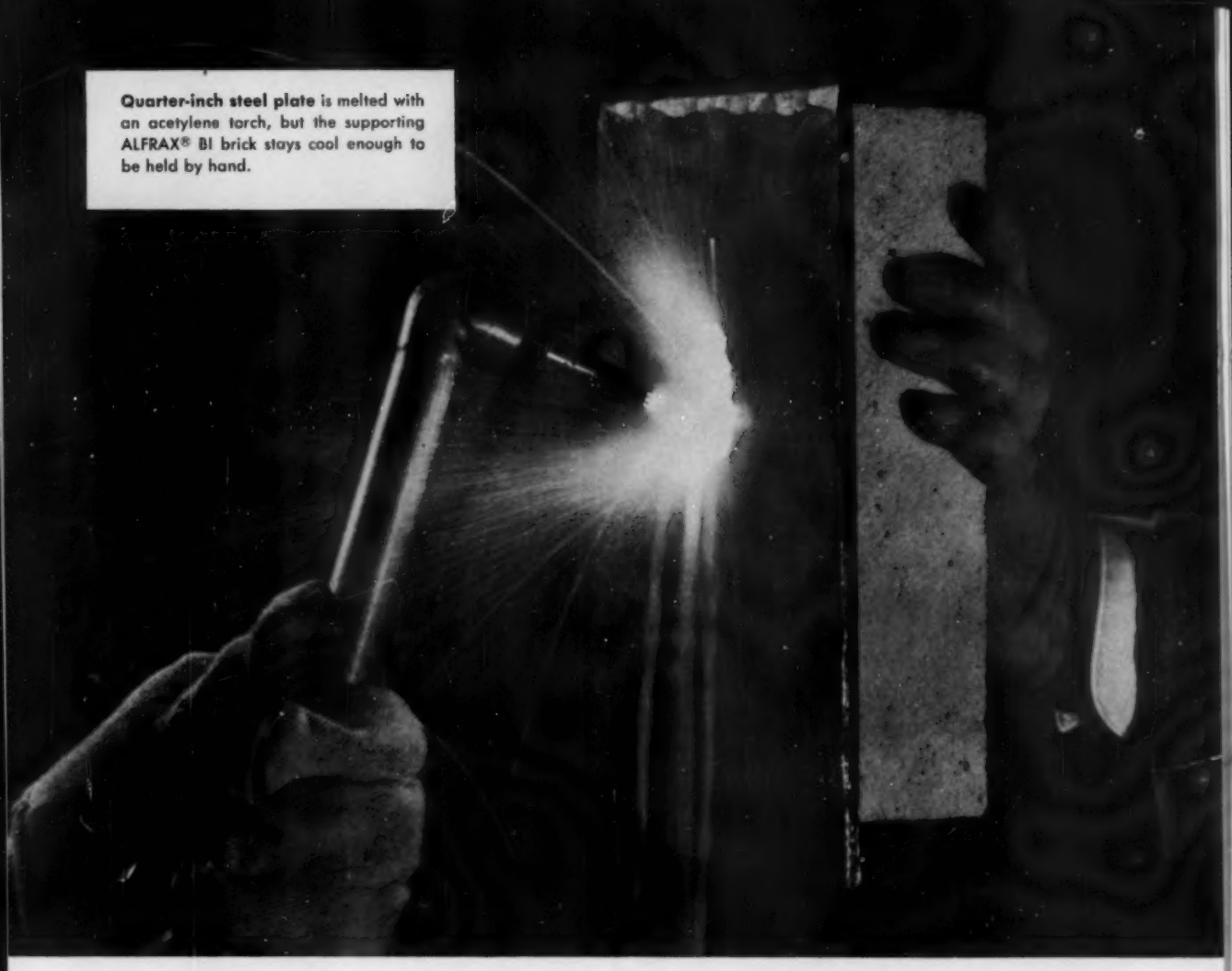

Quarter-inch steel plate is melted with an acetylene torch, but the supporting ALFRAX® BI brick stays cool enough to be held by hand.

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The problem of heat insulation at extreme temperatures is solved by two of Carborundum's refractories:

One is made of fused alumina "bubbles" or hollow spheres, bonded and high fired. These selected bubbles give proper balance between the number of surface temperature drops and total pore space (about 65% porosity) to effectively decrease heat flow between hot and cold faces. The alumina imparts high hot strength to the finished refractory, trade-marked ALFRAX BI. Under a load of 12½ psi and a temperature of 2732° F held for 1¾ hrs., less than 1% contraction occurred. No contraction whatever developed in 5 hour reheat tests at 3092° F. This combination of properties makes ALFRAX BI refractories unique in their ability to insulate at temperatures where other materials are impractical.

The other is FIBERFRAX® ceramic fiber, produced by blowing an alumina-silica fusion. Among its properties are high insulating values, light weight, resiliency, and corrosion resistance. All are retained at 2300° F. In some cases, this fiber can be used successfully up to 3000° F. It is supplied in long and short staple, rope, board, paper, block, blanket, etc.

These products are but two of the many super refractories pioneered by Carborundum. Among them you are almost certain to find answers to your refractory and high-temperature problems. For help, fill in and mail this coupon today.

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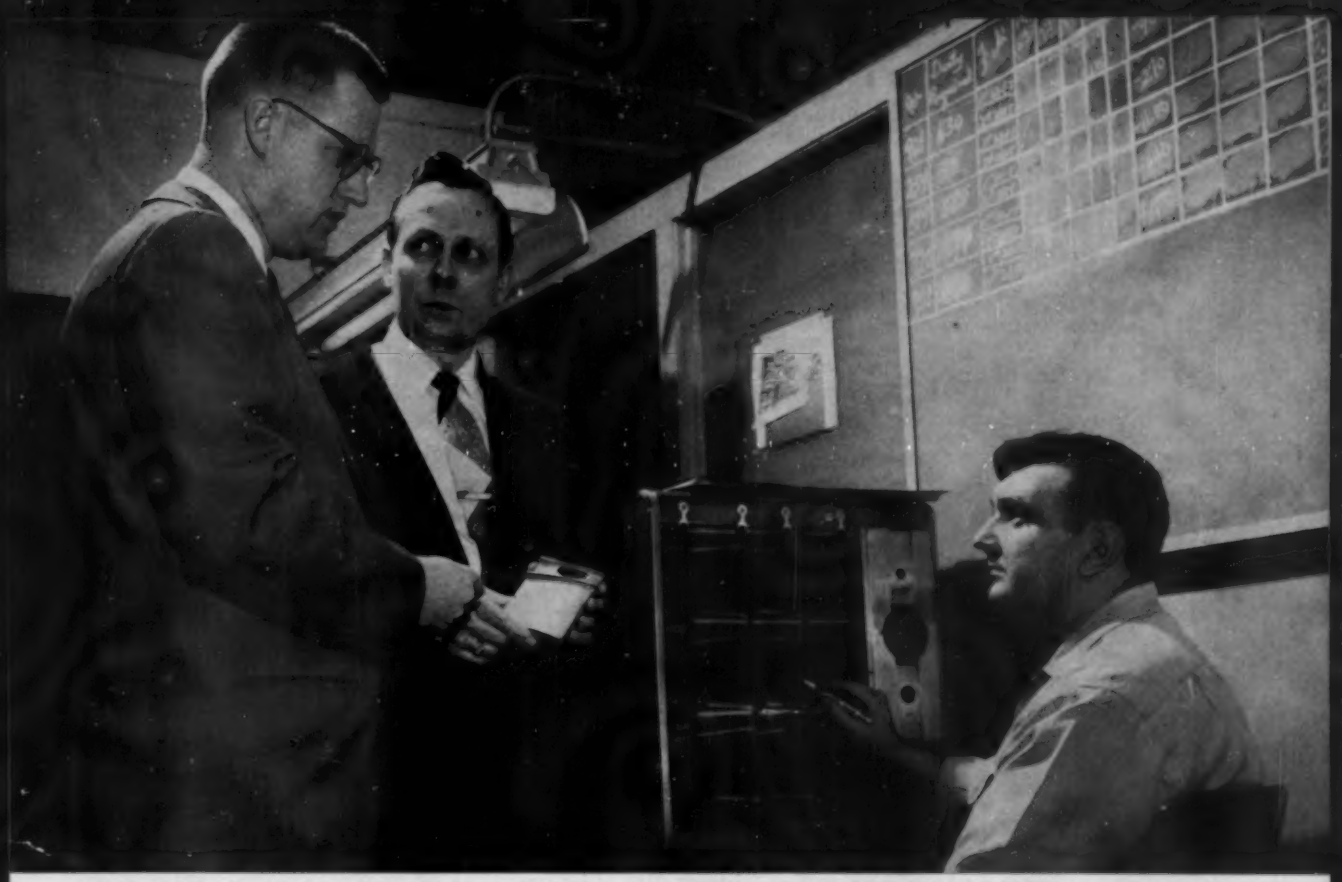

HOWARD FOUNDRY'S Quality Control Manager John F. Pillifant (center) and X-ray Department Foreman Joseph Trempala (seated) are pictured with J. A. Reburn of Du Pont. They discuss radiograph of castings made on dependable, easy-to-read Du Pont Type 510 Industrial X-ray Film.

"Our heavy output of castings demands the consistency and speed of Du Pont x-ray film"

—says Quality Control Manager John F. Pillifant, Investment Casting Division, Howard Foundry Co., Milwaukee, Wisconsin.

TECHNICIAN positions castings for radiographic examination. Fine grain and wide latitude of Du Pont x-ray films simplify detection of minute flaws.

Howard Foundry is a major supplier of investment castings to the aircraft and automotive industries. To insure a faultless product, radiographic examination is used routinely.

Mr. Pillifant reports: "We turn out hundreds of castings a day and each must pass rigid standards. Because of their uniformity and fine grain, Du Pont x-ray films assure us of good radiographs. We stake our company's reputation on x-ray examination and know we can depend on Du Pont x-ray films to give us complete protection!"

X-ray Department Foreman Joseph Trempala adds: "Du Pont films resist abrasion in rough handling, and that's particularly important when we are checking quality of metal from .013 to 1.25 inches. We can always count on accurate readings with Du Pont x-ray films.

"We like the packaging of Types 506 and 510 N.I.F.*, too. The non-interleaved feature not only eliminates darkroom clutter, but also speeds cassette loading."

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High-Temperature Strength of Aircraft Structures

Digest of "Investigation of the Compressive Strength and Creep Lifetime of 2024-T Aluminum Alloy Skin Stringer Panels at Elevated Temperatures", by Eldon E. Mathauser and William D. Deveikis, National Advisory Committee for Aeronautics, Technical Note 3647, May 1956.

SINCE AIRCRAFT STRUCTURES are subjected to elevated temperatures during high-speed flight, a knowledge of the elevated-temperature strength and creep lifetime of structural components is becoming increasingly important. Studies have been made previously by the National Advisory Committee for Aeronautics to obtain experimental data on elevated-temperature strength and creep behavior of plates and multiweb box beams. The present investigation of skin stringer panels is a continuation of the previous program.

Compressive strength tests were made at room temperature and 400° F., and creep tests were performed at 400° F. The experimental results of the strength tests compared satisfactorily with predicted strengths obtained from methods given in the literature for estimating crippling strength of short panels and for predicting column strength of long panels.

In conducting the creep tests, all panels had been exposed at 400° F. for 10 hr. prior to loading. This exposure produced relatively stable material properties that would not be altered appreciably by additional exposure for short periods at the same temperature. Inasmuch as the creep tests were of short duration, the observed behavior of the panels was assumed to reflect structural behavior independent of significant changes in material properties. Buckles were produced in the skin of all panels immediately upon loading. The buckles increased in depth during the creep tests and were accompanied by lateral deflection of the stiffeners until collapse occurred. The results of the creep tests indicated that a progressive decrease in applied stress of as little as 3% could increase panel lifetime by a factor of five times.

A study was also made to determine whether compressive creep curves in the form of time-dependent stress-strain (isochronous) curves could be used to predict panel lifetime. Similar time-dependent stress-strain curves had previously been used by the authors for determining creep lifetime of plates. In order to establish time-dependent stress-strain curves in the present investigation, compressive creep curves for the 2024-T 3 aluminum alloy sheet at 400° F. were obtained from plate specimens tested in grooved fixtures. For the short panels, time-dependent stress-strain curves were used in conjunction with methods that are available for determining crippling strength. For longer panels, stresses that produce creep failure were determined by using both time-dependent stress-strain curves and the curve for experimental-average stress versus unit shortening from a short panel.

Additional experimental creep data for panels of other cross sections and different materials will be needed to determine whether these methods will be satisfactory for general application in predicting panel lifetime. WILLIAM A. AUSTIN

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Grobet File Co. of America, Inc., Carlstadt, New Jersey has eliminated spoilage in the hardening of its fine quality high-speed rotary files by use of Sentry equipment.

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Western Metal Congress and Exposition, Pavilion #4, Booth #1421, Los Angeles, March 25 to 29

See the KENTANIUM* Demonstrations

...how this titanium carbide PERFORMS at 2000° F

One of several demonstrations we will have at the Western Metal exhibit will show the exceptional resistance of Kentanium to oxidation at elevated temperatures. (Note the accompanying report of a recent test.) This suggests how well Kentanium will perform at 2000°F. Come in and see this dramatic demonstration. It quickly demonstrates one of the many unique properties of Kentanium and may suggest applications where it can help you.

...see these other demonstrations

1. **THERMAL SHOCK:** Another demonstration will show the effect on Kentanium when first heated to 2000°F and then cooled to 300°F in approximately one minute. Be sure to see it.
2. **HIGH MODULUS:** This demonstration shows the high rigidity of Kentanium—approximately twice that of the hardest steel alloy. Kentanium has the highest stiffness to weight ratio of any material.
3. **WEAR-RESISTANT** properties of Kentanium while heated to a high temperature and subjected to severe wear conditions.

...and see these high purity (99.5%) metals and compounds

Columbium (Niobium)—powders, granules and bars
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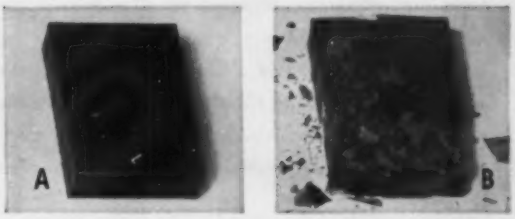

KENTANIUM unharmed at 2000°F while heat-resistant nickel-chrome alloy disintegrates

Here's proof of Kentanium's exceptional resistance to oxidation at high temperatures.

A square of K161B Kentanium and a similar square of well-known, heat-resistant 35 chromium-15 nickel alloy were exposed for 120 hours in an unsealed muffle furnace heated to 2000°F. The accompanying photographs vividly show how each piece was affected. While Kentanium (See "A") is still good for hours of exposure at high temperatures, the nickel-chrome alloy (See "B") has oxidized badly and has begun to disintegrate.

Combined with its high resistance to oxidation, Kentanium has great strength and resistance to corrosion.

These characteristics suggest how well Kentanium will perform in such applications as furnace parts, heat-treating fixtures, quench guide rings, turbine blades, nozzle vanes, bushings and other parts where strength at high temperatures, plus high resistance to oxidation, are factors.

C-30160

If you do not plan to attend the Western Metal Conference, send for copies of our "Characteristics" booklet No. 111-A and "Design" booklet No. 222. Write KENNAMETAL INC., Dept. WMS, Latrobe, Pennsylvania.

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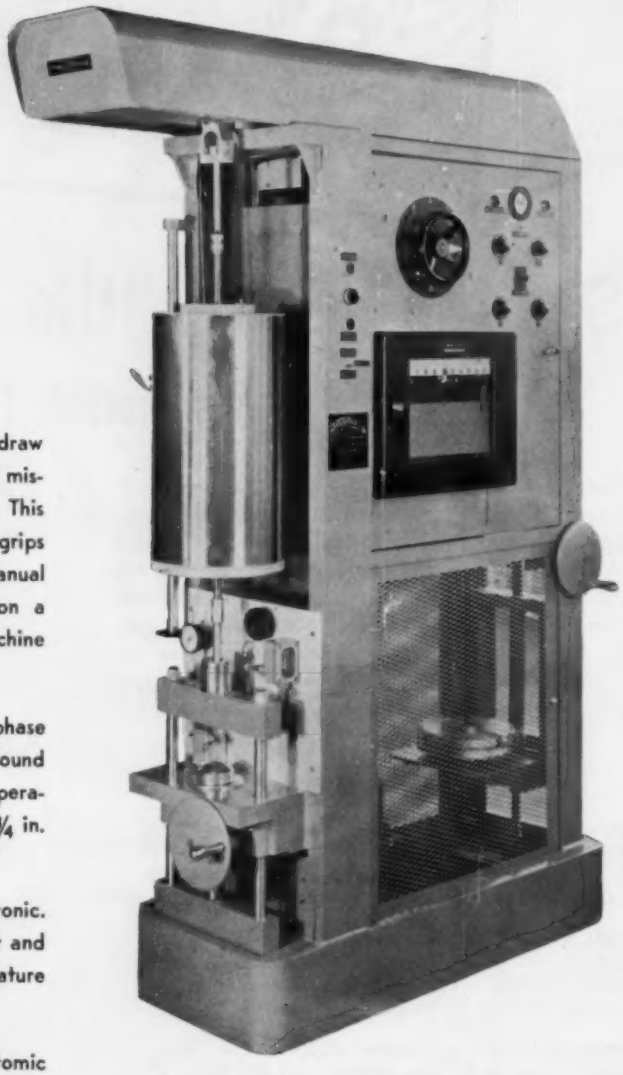
New Creep Rupture Testing Machine



loads specimen to 20,000 lb. under adjustable temperature to 2,200 degrees F.

WEIGHT is applied by a precision way guided draw head that eliminates torsional strain and axial misalignment on the .050-in. diameter specimen. This is an exclusive Arcweld design. Self-aligning grips are heat-resisting alloy. Takeup is motorized manual or automatic. Counterbalance weights rest on a manually-adjustable platform within the machine housing.

FURNACE is our Type-X for 220-volt single-phase ac. It is designed for five-zone operation, is wound with Chromel or Kanthal resistance wire for operation to 2,200 deg. F. It measures 12 in. o.d., 4¾ in. i.d., 22 in. in height.

CONTROL of lever arm null position is electronic. Furnace temperature control is by a Powerstat and individual rheostats for each of the five temperature zones.

APPLICATION is primarily for research in atomic energy to determine behaviour of metals in the presence of radio-active substances at elevated temperatures. The machine can be supplied with salt-bath fixtures for such applications. 12,000, 16,000 and 20,000 lbs.

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New Relaxation Tester! New Rapid Heat Testing System for Guided Missile Work and Weld Ductility Tests!

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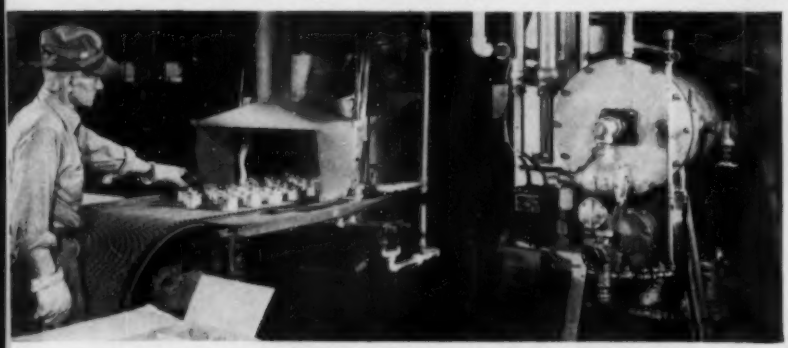
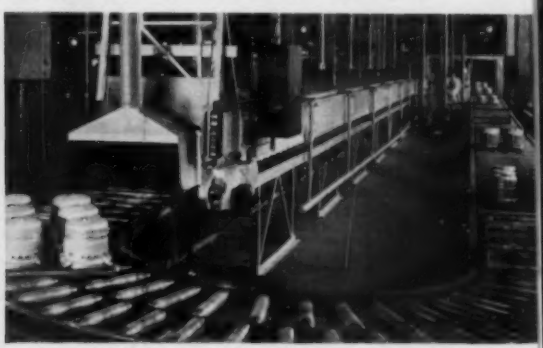
Versatility of furnace brazing is shown in these applications. Complex assemblies like the cam-and-gear cluster on the left can be fabricated from punched laminations brazed securely in a General Electric mesh-belt furnace. Required contours are obtained without expensive machining from solid stock.

Thin sections can be joined to heavy sections to produce light-weight rigid structures without sacrificing strength or inducing local distortion. Honeycomb structure at top center weighs about one fourth as much as solid assembly of same rigidity. It is typical of design improvements made possible by brazing in General Electric furnaces.



Continuous production of small parts in this General Electric mesh-belt furnace is carried out by loading assemblies directly on the belt. Protective atmosphere equipment, at right, eliminates need for flux in most cases, keeps parts clean enough to be passed directly from the furnace, without cleaning or pickling.



Automatic charging, and discharging and return conveyors of this General Electric roller-hearth furnace make it almost self-operating, reduces handling costs. G-E roller-hearth furnaces handle heavy assemblies and are well suited for automated lines.

GENERAL ELECTRIC SELLS
A COMPLETE LINE OF
HEAT PROCESSING EQUIPMENT

FURNACES • METAL-SHEATH • INDUCTION

Produce Complex Assemblies Faster and at Less Cost with General Electric Furnace Brazing

Two or more metals can be joined, as in the bellows housing shown above. The steel flange is furnace-brazed to a brass shell, using preplaced rings of silver brazing alloy. The desirable qualities of each metal are retained.

General Electric furnace brazing speeds production of really "tough" assemblies—and often does it at less cost than you can do it by your present methods.

For example, here are three types of work where you can improve production with furnace brazing.

You can make complex assemblies from already formed components, and save both material and machine costs.

You can make assemblies of two or more different alloys without changing the desirable characteristics of either.

You can join thin sections to heavy sections without sacrificing strength or inducing local distortion.

These characteristics of furnace brazing can be used in a number of widely different production setups. And General Electric's complete line of furnaces and associated equipment lets you pick the proper furnace to introduce furnace brazing into your particular setup—economically, efficiently.

Cost reductions are typical with furnace brazing because labor content per assembly goes down while output goes up. Waste is reduced since assemblies can be built up of components instead of being machined from solid stock. Uniformity of results frequently leads to reduced inspection costs.

Improved products are the rule with furnace brazing. Life of assemblies is increased because joints have high strength, resist vibration and impact, and are uniformly tight. Assemblies show little or no distortion, since they are free from localized strains. They present a good finished appearance without afterwork because the brazing alloy forms neat fillets. Also protective furnace atmospheres eliminate formation of oxides and do away with the need for flux in most cases.

Increased production over other joining methods is possible, since many joints can be brazed simultaneously. Furnace brazing is adaptable to continuous production, with increasing output.

For a careful analysis of your furnace brazing needs call your General Electric Heating Specialist. Ask him to show you how you can benefit by using furnace brazing. You can reach him at your local General Electric Apparatus Sales Office. If you prefer, send in coupon below for bulletins describing furnace brazing operations and equipment.

GENERAL ELECTRIC

Development work is done in this General Electric box furnace, which could also be used for job-lot production. Low in first cost, General Electric box furnaces need little maintenance.

FREE PROCESS BULLETINS

Section J721-8,
General Electric Company
Schenectady 5, New York

Please send me free bulletins checked below.

MODERN HEAT PROCESSING BULLETINS

- ☐ Furnace and Induction Brazing, GEA-5889
- ☐ Protective Atmospheres, GEA-5907

TECHNICAL BULLETINS

- ☐ How and Where to Use Furnace Brazing, GEA-3193
- ☐ Electric Furnace Brazing, GER-106
- ☐ Furnace Brazing of Machine Parts, GER-339

NAME.....

COMPANY.....

ADDRESS.....

CITY.....STATE.....

Mesh Belt

Rotary Hearth

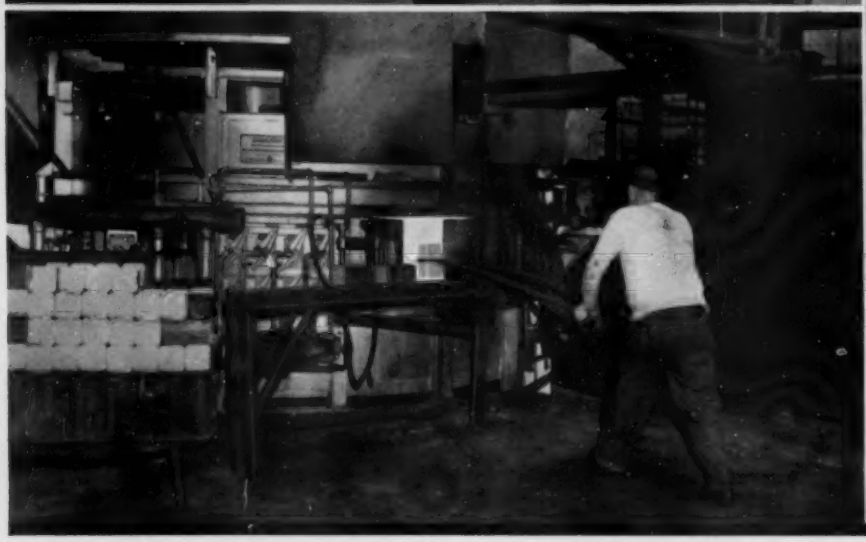
Tower

Cylindrical Bell

Metal-Hearth

Electronic Induction

COMPLETE AUTOMATION is achieved by integrating Selas Gradiation® Heating into Chambersburg Engineering Company's new, Cecomatic forging process. Brass slugs, up to 1⅛" diameter x 3¼" long, are heated to 1500°F and delivered automatically to the Impacter at production rates which can be varied from 20 to 40 forgings per minute.



STEEL BILLETS, up to 7" square, are heated in this Selas Gradiation furnace at Lansdowne Steel and Iron Company. Fast heating to 1850°F . . . at rates of 2 to 5 minutes per inch of thickness . . . virtually eliminates scale, thereby reducing billet weight 10%. Fast heated billets are forged at temperatures 300°F below conventional methods.

IMPROVED FORGEABILITY plus savings in labor, time, floor space . . . with SELAS HEAT PROCESSING

Improved forgeability, directly attributable to ***FAST*** heating, reduces power requirements at the usual forging temperatures, or, for given power applied, permits an increase in the amount of flow or deformation. More importantly, this increased capacity for hot work can be used to advantage to permit working metals at lower temperatures, with no increase in applied work.

Whether your forging requirements call for fully automatic or manual handling operations, you always get these benefits from Selas Gradiation heating: rapid start-up . . . low cost per work-piece heated . . . virtual elimination of scale . . . precise controllability . . . ***FAST*** heating which helps pace production . . . compact equipment which reduces floor space requirements.

In heat treating, brazing, forging, strip-heating and other continuous operations involving both ferrous and nonferrous metals, Selas engineers can design Gradiation heating to help speed production, improve product quality, reduce costs.

Our engineers will be glad to discuss how Selas Gradiation methods can be tailorcd to your heating needs. Address Dept. 33.

SELAS
CORPORATION OF AMERICA
DRESHER, PENNSYLVANIA

Heat and Fluid Processing Engineers

DEVELOPMENT • DESIGN • CONSTRUCTION

Here's the Nation's NO. 1 Nitrogen Gas Generator

Only Gas Atmosphere's new Nitrogen Generator has all the features you have asked for in a production generator. It comes as a COMPLETE PACKAGED UNIT ready to be set on stream with a minimum of make ready. EXCLUSIVE AUTOMATIC TURN-DOWN enables production coincident with demand, eliminating gas waste. SIMPLIFIED RATIO CONTROL assures uniform gas analysis always. SINGLE BURNER OPERATION means easier combustion control. This new generator develops HIGHEST PURITY NITROGEN and, where required, CO_2 can be obtained from the same unit simultaneously. Here is truly the nation's top nitrogen generator. Be sure you look into it before you buy.

gas Atmospheres, inc

equipment for producing industrial gases

20011 WEST LAKE ROAD CLEVELAND 16, OHIO

The temperature of this Wissco Rod Reinforced Belt varies from 2,050° F. to room temperature as it conveys steel fittings through a brazing furnace and into a water-cooled chamber.

WISSCO BELTS *and the Mossberg Pressed Steel Corporation*

The story of Wissco Belts is best told by their users. For instance, Mr. Robert B. Housman, design engineer for Mossberg Pressed Steel Corporation, Attleboro, Mass., reports:

"We obtained over a 100% increase in belt life—simply by switching to Wissco Belts."

And Mr. Housman goes still further: "What's more, the change to Wissco Belts enabled us to reduce belt maintenance costs by 15% and to spend 20% less time cutting slack out of our belts. We know of no other belt that can do a better job of withstanding the constant heating and cooling cycle of the brazing furnace and still maintain its inherent strength and consistency."

This Wissco Belt conveys steel fittings for braiding machines through the brazing furnace and into a water-cooled chamber. Normal belt operation is for an 8-hour, 5-day week; however, the furnace is put on a 16-hour day during peak months. This puts an additional strain on the metal belt since the 2,050° F. furnace temperature must be maintained around the clock under these conditions.

If yours is a high temperature operation . . . or any processing or conveying job . . . it'll pay you to get the complete Wissco Belt story. Contact our nearest sales office today.

THE COLORADO FUEL AND IRON CORPORATION—Denver and Oakland
WICKWIRE SPENCER STEEL DIVISION—Atlanta • Boston • Buffalo • Chicago • Detroit
New Orleans • New York • Philadelphia
CF&I OFFICES IN CANADA: Montreal • Toronto

CF&I **WISSCO BELTS**
PRODUCT OF WICKWIRE SPENCER STEEL DIVISION
THE COLORADO FUEL AND IRON CORPORATION

4633

XX

This is the twentieth of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many in this field, including men of broad experience who may find it useful to review fundamentals from time to time.

Flame-Hardening Alloy Steels

When the surface of steel is subjected to direct application of flame and heated above the transformation range, then hardened by quenching, the process is known as flame-hardening. Its primary purpose is to surface-harden without affecting core properties. Jets of flame are played directly on the steel, and hardness penetration can be made to vary considerably. Usually in alloy steels this depth will range from 0.03 to 0.12 in., the actual figure depending upon the method of heating and quenching used.

Unlike carburizing, flame-hardening does not involve the absorption of extraneous elements by the steel. There is no alteration of the chemical composition. To put it simply, the steel must have its own self-hardening characteristics; cannot be dependent upon carbonaceous salt baths, gases, etc.

Flame-hardening is not a substitute for the conventional furnace method. Each has its uses. The particular virtue of flame-hardening is that the flames can be directed to localized areas. The furnace, on the other hand, is generally more economical and feasible when parts produced in large quantities must be hardened all over.

Any type of hardenable steel, alloy or carbon, can be flame-hardened, and there will usually be no scale or pitting. The alloy content is the governing factor when determining the quench. In some cases a rapid quench is required; in others, it can be as slow as air-cooling. Tempering presents no problems, for flame-hardened steel can be tempered as if hardened to the same point by other methods.

A list of typical flame-hardened parts would include such familiar items as gear and sprocket teeth, and certain types of cams and rollers, shoe treads, etc. This list is by no means exhaustive; it could include many other parts that often require a localized hardening treatment, especially for wear-resistance.

When seeking information about flame-hardening methods, please feel free to consult with our technical staff. Bethlehem metallurgists will gladly cooperate, and you can depend upon their suggestions. You can rely on Bethlehem, too, as a source of alloy steels, for Bethlehem makes the complete range of AISI standard grades, as well as special-analysis steels and all carbon grades.

If you would like reprints of this series of advertisements from No. I through No. XVI, please write to us, addressing your request to Publications Dept., Bethlehem Steel Company, Bethlehem, Pa. The first 16 subjects in the series are now available in a handy 32-page booklet, and we shall be glad to send you a free copy.

BETHLEHEM STEEL COMPANY
BETHLEHEM, PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation. *Export Distributor:* Bethlehem Steel Export Corporation

BETHLEHEM STEEL

BETHLEHEM STEEL

Talide Die

cuts molding cost

7¼¢ to 1¢...

● Simonds Abrasive Company, a leading producer of abrasive wheels, called in a Talide Die Engineer to help reduce excessive die costs. The highly abrasive action experienced in molding the wheels to shape cut service life of hardened steel dies to 3000 wheels. A Talide carbide die having 6" I.D. was designed and, due to its super hard and dense structure, approximately 25 times the number of wheels were pressed! $4,708.80 worth of steel dies would have been required to equal the production of this one $690.00 Talide die. **Metal Carbides Corporation, 6001 Southern Boulevard, Youngstown 12, Ohio.**

SIMONDS ABRASIVE COMPANY

GRINDING WHEELS ABRASIVE GRAINS

TACONY AND FRALEY STREETS PHILADELPHIA 37, PENNA.

TELEPHONE JEFFERSON 5-9100

February 13, 1956

Metal Carbides Corporation
107 E. Indianola Ave.
Youngstown 7, Ohio

ATT: Mr. R.T. Beeghly

Dear Mr. Beeghly:

At the request of your Mr. J.R. Macek, I am forwarding information about our molding die costs for the manufacture of grinding wheels pressed on an automatic press.

When we first began to use automatic presses in our process we set up with steel dies which gave us a molding die cost of $.0725 per piece produced. We then went to Metal Carbides dies which gave a per piece die cost of $.0175. Further changes to a different grade have given a per piece die cost of $.015.

We have recently had one of these dies reworked and have noted still further increase in life and a per piece die cost of $.0106.

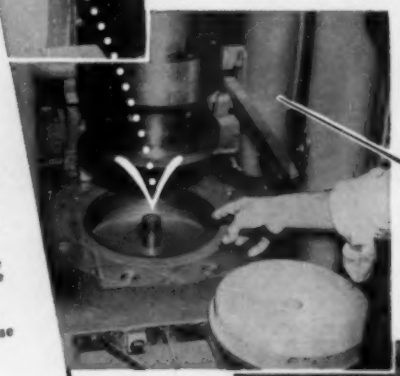
Needless to say, we are quite pleased with the results obtained. If we can produce further information, please let us know.

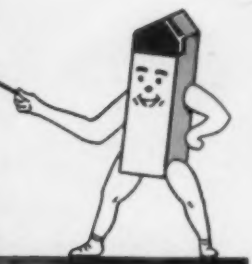
Very truly yours,

SIMONDS ABRASIVE COMPANY

William Kohn
Tool Engineer

WK:mj





DEEP DRAW DIES

25,680,000 outlet boxes drawn with TALIDE—Steel dies average 700,000.

POWDERED METALLURGY DIES

Compacting highly abrasive chemical powders, TALIDE Pill dies last 4 months, steel dies wore out in 6 hours.

HEADING AND EXTRUSION DIES

Cold-heading ¼" C-1008 steel rivets, TALIDE dies produced 11,200,000 pieces, other carbide dies only 3,500,000.

Send for Catalog 56-G or ask for Talide Die Engineer to call

METAL CARBIDES CORPORATION

MC

TALIDE®

YOUNGSTOWN 12, OHIO

HOT PRESSED AND SINTERED CARBIDES • VACUUM METALS
HEAVY METAL • ALUMINUM OXIDE • HI-TEMP. ALLOYS
OVER 25 YEARS' EXPERIENCE IN TUNGSTEN CARBIDE METALLURGY

X-ray inspection of vital aircraft landing gear parts. Westinghouse now distributes portable Balteau line.

Your problem might be solved by fluoroscopic inspection. The exclusive Westinghouse Fluorex Image Amplifier extends the field of internal inspection with fluoroscopy.

Radiographic inspection of large castings is accomplished faster with the stationary 250 KV Constant Potential Unit.

From Aircraft Parts to Giant Castings

Westinghouse Industrial X-ray Equipment Can Handle Any X-ray Inspection Problem—From Aircraft to Giant Castings

Now – with transportable units, stationary units up to 250 KV capacity, production line units and versatile fluoroscopic units including image amplification, Westinghouse solves your most difficult internal inspection problems.

If you feel that our staff of Industrial X-ray Engineers can assist you in any way, please write: Westinghouse Electric Corporation, X-ray Department, 2519 Wilkens Avenue, Baltimore 3, Maryland.

YOU CAN BE SURE... IF IT'S

Westinghouse

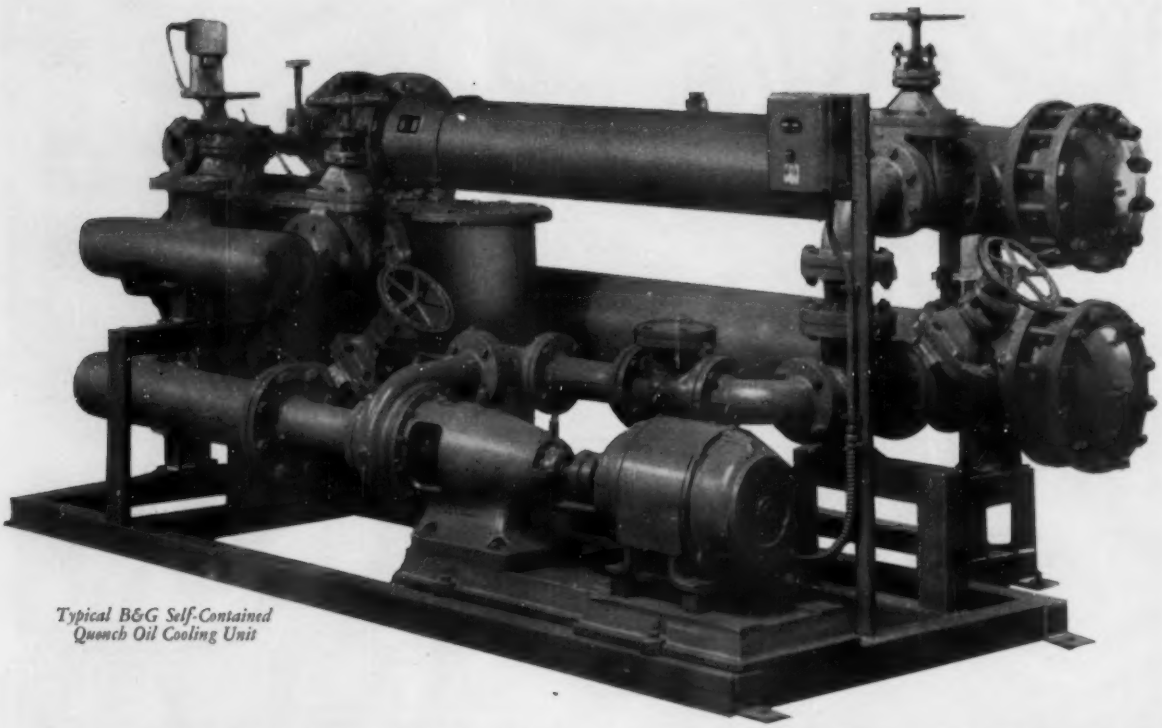
INDUSTRIAL X-RAY

X-RAY DEPARTMENT

Westinghouse Electric Corporation

2519 Wilkens Avenue, Baltimore 3, Maryland

J-08333



Typical B&G Self-Contained Quench Oil Cooling Unit

Complete in every detail for

Controlled

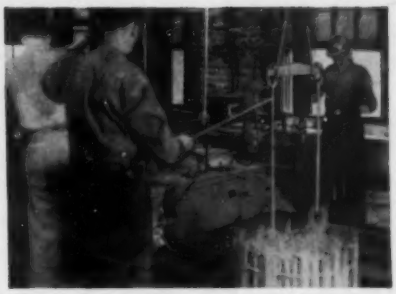
QUENCH OIL COOLING

Proper control of quench oil temperature is the certain way to maintain uniform quality in heat-treated metals and to avoid excessive sub-standard rejects. The only question is how to provide that control in the most practical, efficient manner.

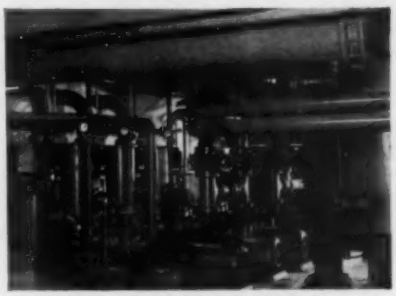
While the individual components of an oil cooling installation can be purchased and assembled on the job, the trend today is to install completely factory-assembled oil cooling systems.

To meet this demand, B&G offers completely self-contained oil cooling units—integrated in every respect—ready for immediate operation. These units are engineered to your specific requirements.

Whether your heat treating volume is large or small, the services of the B&G engineering department are available. Your request for information will receive prompt attention.



Every piece uniform in quality because uniformly quenched



Battery of B&G Quench Oil Coolers

B&G QUENCH TANKS

Properly designed to induce maximum turbulence in the quench oil. B&G Quench Tanks are available in standard models or can be built to meet any specific quenching requirement.

●

Send for this combined Catalog and simplified Selection Manual for B&G Self-Contained Quench Oil Coolers

B&G

Hydro-Flo*

OIL QUENCHING SYSTEMS

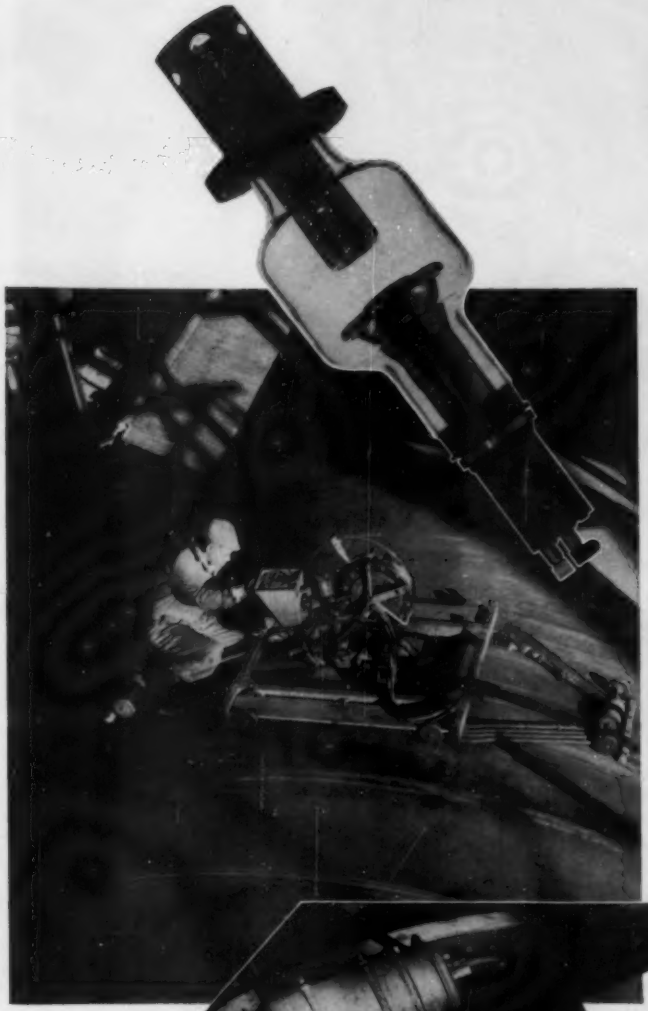
BELL & GOSSETT COMPANY
Dept. ES-16, Morton Grove, Illinois

Canadian Licensee: S. A. Armstrong, Ltd., 1400 O'Connor Drive, W. Toronto.

*Reg. U.S. Pat. Off.

Pressure Hull Inspection for Nuclear Powered Submarines with

MACHLETT EG-250 X-RAY TUBE



Electric Boat Division of General Dynamics Corporation must perform highly critical radiographic inspection on the thousands of feet of circumferential and transverse butt welds on the pressure hull of each submarine it constructs.

On the nuclear powered submarines constructed and now under construction the Machlett EG-250 x-ray tube is used for all large scale inspection of the pressure hull weldments.

One apparatus manufacturer alone has now used—in a wide variety of applications—more than one hundred EG-250 anode grounded x-ray tubes in gas insulated lightweight x-ray tubeheads.

For exacting inspection under adverse environmental conditions the Machlett EG-250 provides excellent, reliable performance.

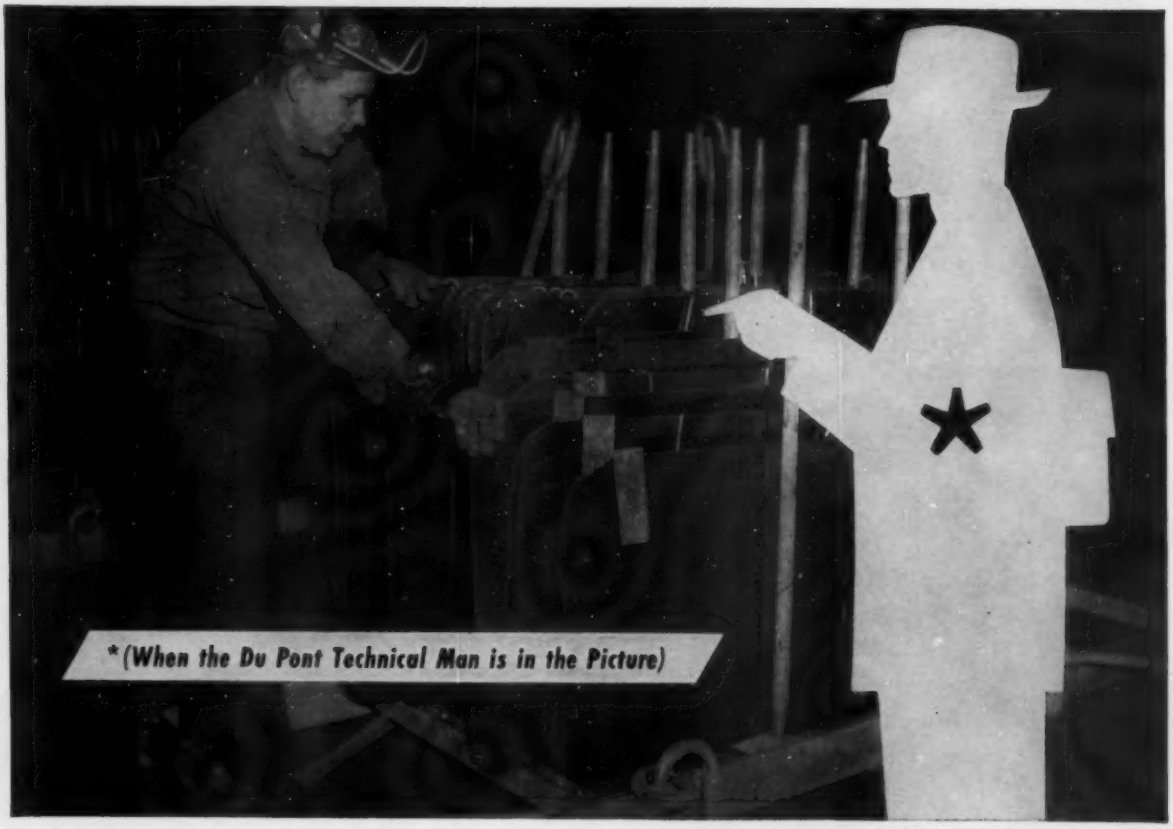
Machlett **EG-250** x-ray tube, used in portable gas insulated tubehead, is employed for weld inspection on pressure hull of nuclear powered submarine SSN 578, Skate.

MACHLETT — FIRST IN INDUSTRIAL ELECTRON TUBES

MACHLETT LABORATORIES, INCORPORATED

Springdale, Connecticut

You Get Practical Help in Descaling



DU PONT technical men bring fresh insight into your descaling operation. Their training and experience with the Sodium Hydride Descaling Process enables them to see where steps can be saved . . . to recognize conditions that may eventually lead to trouble, and to know where new developments can be applied to speed and improve descaling.

When you have a question, one of these Du Pont technicians is only a phone call away. He's equipped to analyze your process, to recommend changes where necessary. He has in back of him the finest in laboratory and technical facilities.

Best of all, there is never any obligation for this service. Du Pont's technical representatives are there to see that Du Pont chemicals are used to their maximum efficiency and that your descaling operation is the most efficient possible for your requirement. Electrochemicals Department, E. I. du Pont de Nemours & Co. (Inc.), Wilmington 98, Delaware.

DU PONT
REG. U. S. PAT. OFF.

Better Things for Better Living . . . through Chemistry

*Technical Representative at your Call

***IN BOSTON:**
R. H. McCahan, *HAncock 6-1714*

***IN PHILADELPHIA:**
R. H. Goodman, *MIdway 9-1420*

***IN CINCINNATI:**
H. W. Kennedy, *PArkway 1-5253*

***IN CHICAGO:**
L. J. Schustik, *INdependence 3-7250*

***IN NEW YORK:**
W. D. Jeffries & R. H. Goodman, *LOngacre 3-6440*

***IN CLEVELAND:**
L. W. McOmber & E. C. Friedl, *LOngacre 1-1580*

***IN DETROIT:**
D. W. Hill & J. B. Hitchcock, *UNiversity 4-1963*

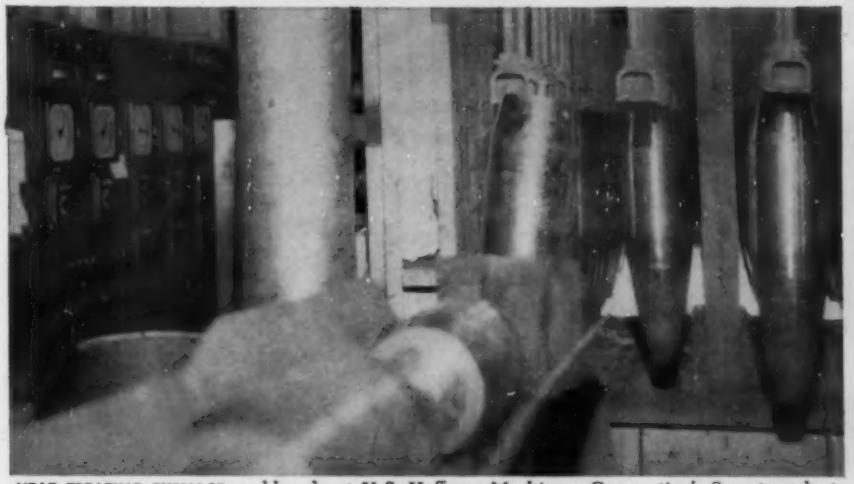
***IN EL MONTE, CALIFORNIA:**
E. D. Marcum, *CUmberland 3-2761*

SODIUM HYDRIDE PROCESS FOR POSITIVE DESCALING

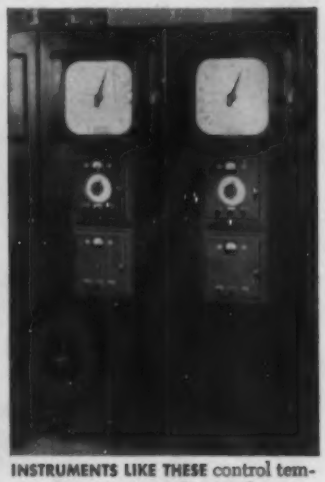
BRISTOL'S

Instrumentation News

• News of instrumentation and automatic control in industrial heating and metallurgy •



HEAT TREATING FURNACE—cold end—at U.S. Hoffman Machinery Corporation's Scranton plant. Heat treatment of projectiles, seen entering furnace at right, is automatically controlled by instruments at left.



INSTRUMENTS LIKE THESE control temperatures in rotary Hagan furnaces at U.S. Hoffman Machinery Corporation's plant. One of six installations.

World's largest hot-forge shell plant gets Bristol control

Continuous heat control is a must in the manufacture of high-explosive shells for the U.S. Army Ordnance Corps.

That's why you find Bristol Electronic Dynamaster* Pyrometer Controls at U.S. Hoffman Machinery Corporation's Scranton, Pa. plant—the world's largest hot-forge shell installation.

Rotary furnaces, built by George J. Hagan Co., heat the steel billets. Bristol control systems, using round-chart Bristol Dynamaster Pyrometers, continuously monitor and regulate the heat in three zones in each of these furnaces.

After forging and before machining, the shells are heat treated in a two furnace setup. Surface Combustion furnaces, also controlled by Bristol Pyrometers, heat the shells in the first stage before quenching, and second stage after quenching.

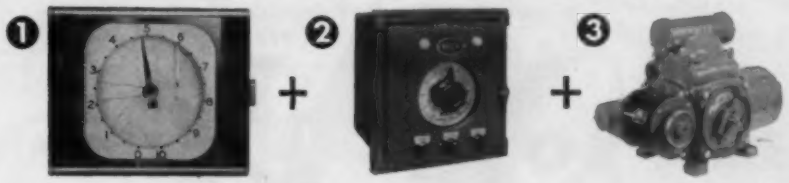
Bristol Series 536 Free-Vane* Electronic Pyrometers automatically cut off the oil in case of furnace overheating.

Bristol Pyrometers provide precise temperature control for any industrial heating installation. You'll find complete specifications and prices in Bulletin P1260. Write for your copy today. The Bristol Company, 106 Bristol Road, Waterbury 20, Connecticut. 4.44

*T. M. Reg. U. S. Pat. Off.

Here are the basic elements for finer temperature control. Hundreds of variations available.

1. Bristol Round-Chart Dynamaster Electronic Pyrometers.
2. Control relay.
3. Motor operator—for proportional positioning of final control units, such as valves, burners, rheostats.



There's a Bristol Controller for every furnace and oven.

BRISTOL *TRAIL-BLAZERS IN PROCESS AUTOMATION*

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

converter powered furnaces mean flexible melting

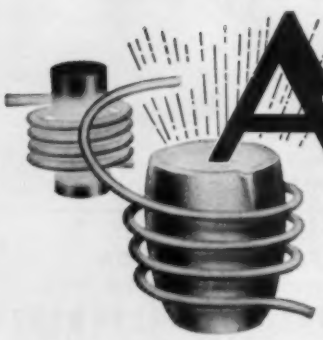
For Precision Casting

Converter powered Ajax-Northrup furnaces have been the birthplace for just about every important alloy discovered in the last quarter-century. But the same economy and flexibility that make them a laboratory necessity make them just as important to industry. In fact, many of today's best known precision casting companies were started with a single Ajax-Northrup high frequency furnace powered by a spark gap converter.

One of the most successful, Precision Metalsmiths, Inc., Cleveland, Ohio, still finds converter powered furnaces ideal for all melting. Because heating must be fast, and the resultant alloys must be pure, high frequency induction heat is the only answer. And the large variety of alloys to be melted—some 92 different ferrous and non-ferrous alloys—makes converter operation highly desirable. The company's four furnaces *could* be powered by a single motor-generator set. But powering each furnace with an individual spark gap converter achieves maximum efficiency and versatility at minimum cost.

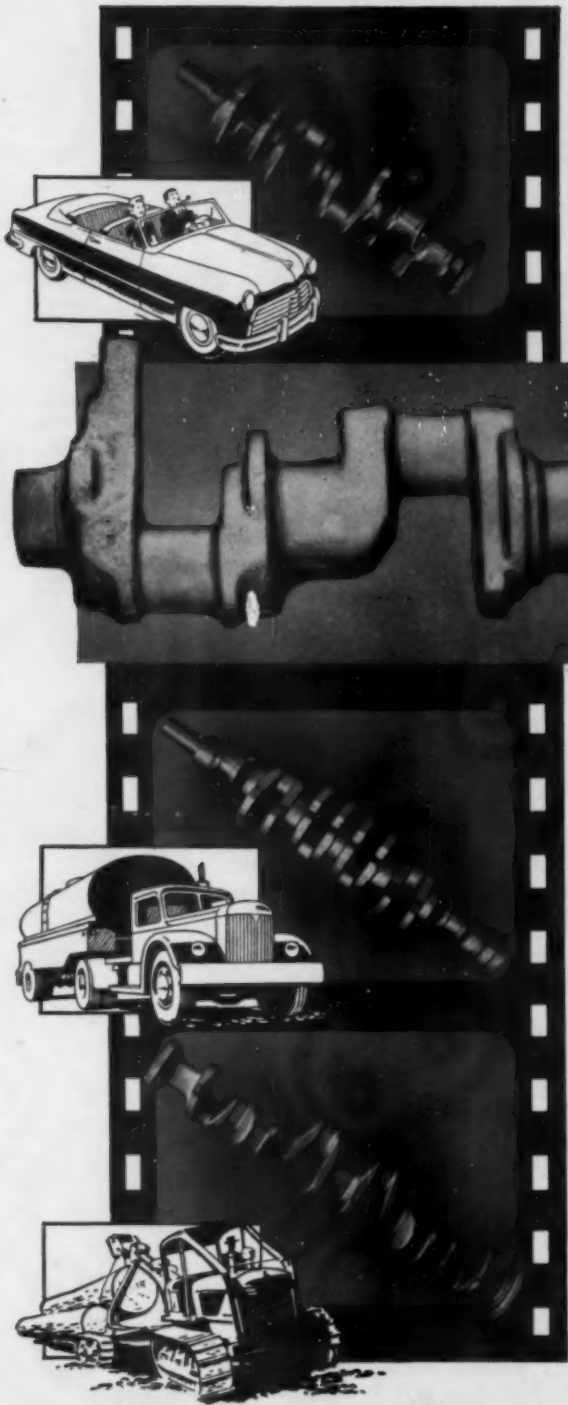
Precision Metalsmiths' need for flexibility is not altogether typical. But it does serve to underscore the undeniable advantages of converter powered Ajax-Northrup furnaces for precision castings. Additional details on how converter powered high frequency induction furnaces could improve your operation, are available from Ajax Electrothermic Corp., Trenton 5, New Jersey. Request Bulletins 14-B and 27-B.

Associated Companies: Ajax Electric Company — Ajax Engineering Corporation



AJAX NORTHRUP SINCE 1916

INDUCTION HEATING-MELTING



There's no substitute for the FORGED crankshaft

Crankshafts have been made successfully by other methods of fabrication and have proven to be *good enough* for certain non-critical applications—but for maximum dependability of the modern, compact, high compression, high torque engine a forged crankshaft is essential.

The forging process assures, to the greatest degree possible, uniformity and predictability of physical properties with a minimum variance from piece to piece or from one location to another in the same piece.

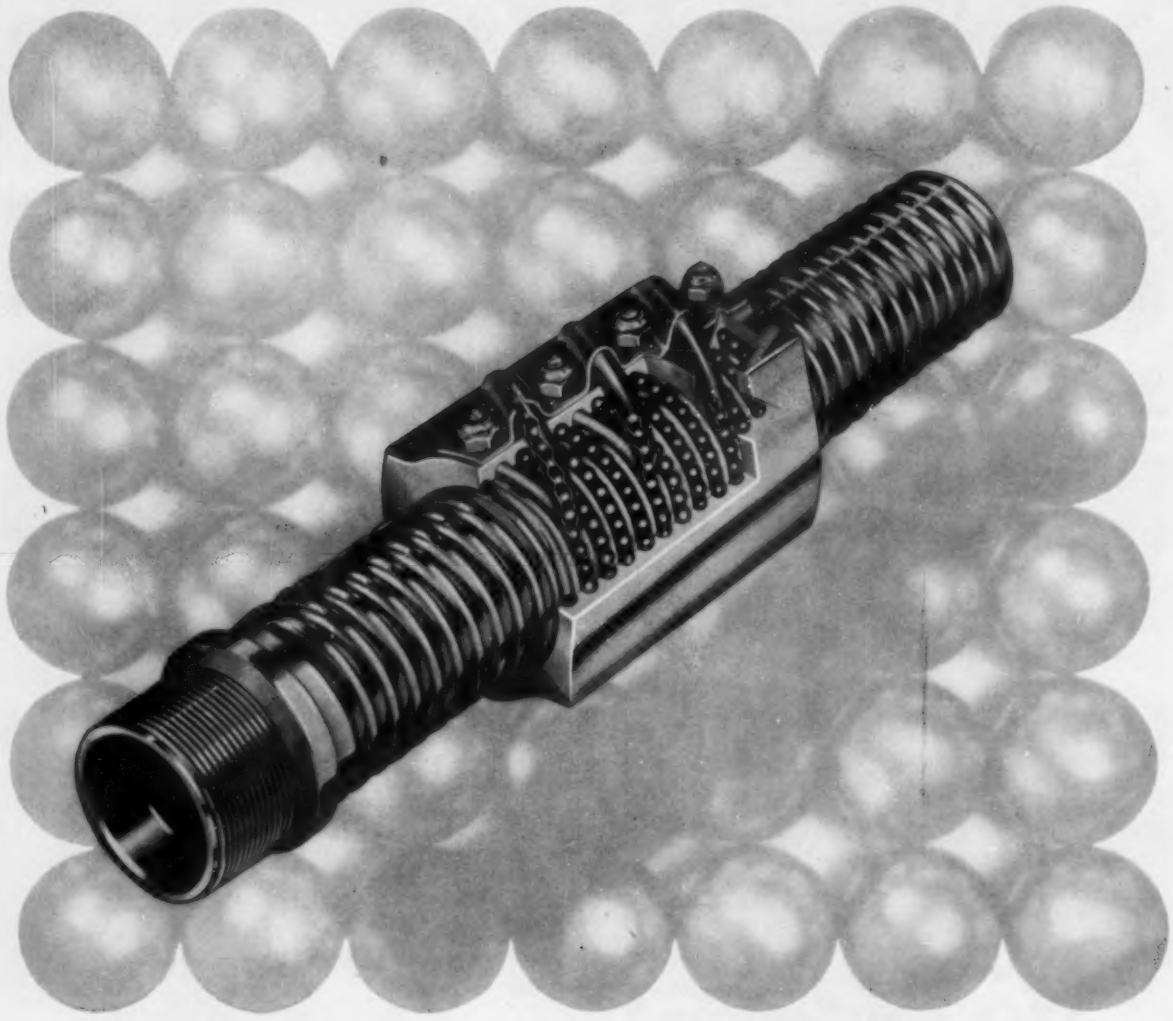
Wyman-Gordon has been forging crankshafts since the beginning of the internal combustion engine era and today produces more crankshafts for a greater variety of applications than any other company in the world. In a crankshaft there is no substitute for a forging, and in a forging there is no substitute for Wyman-Gordon quality and experience.

WYMAN-GORDON COMPANY

Established 1883

WORCESTER 1, MASSACHUSETTS
HARVEY, ILLINOIS • DETROIT, MICHIGAN

FORGINGS OF ALUMINUM • MAGNESIUM • STEEL • TITANIUM



how Vacuum Metals' FERROVAC boosts ball bearing screw life up to 400%...

Ball bearing screw assemblies, first used in automobile steering mechanisms, are now found in such critical applications as the actuation of landing gear and control surfaces of aircraft and guided missiles. And it was in tough jobs like these that the assemblies failed in fatigue. Then a leading manufacturer tried vacuum-melted FERROVAC® for the balls – and service life rose as much as 400% over the original life. Here's why...

Vacuum melting improves fatigue properties – It literally sucks gaseous impurities – focal points for fatigue failure – from the molten metal. Vacuum-melted metals are cleaner, purer, tougher. And cleanliness means an added bonus in fewer rejects.

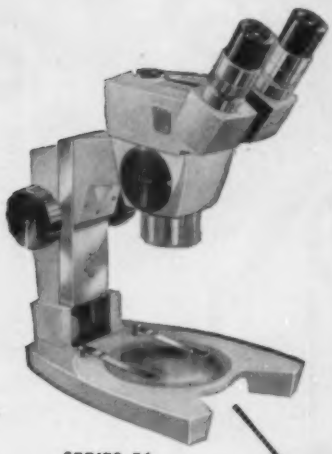
Only Vacuum Metals gives you one-source service – Vacuum Metals Corporation, Division of Crucible Steel Company of America, provides a fully integrated service from melting and casting through mill rolling and nationwide distribution of finished mill products. And you can get not only small experimental lots, but now, thanks to our new 2500 lb. induction furnace – the nation's largest – you can also get large-scale continuous production quantities of vacuum-melted metals. If you have an application which these unique metals may improve, please write giving full details. *Vacuum Metals Corporation, Division of Crucible Steel Company of America, P. O. Box 977, Syracuse 1, New York.*

VMC®

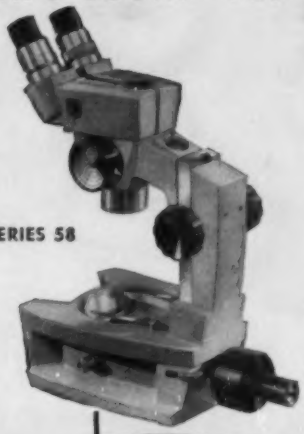
VACUUM METALS CORPORATION

Division of Crucible Steel Company of America

ON DISPLAY AT HARSHAW'S BOOTH #726—WESTERN METAL SHOW



SERIES 56



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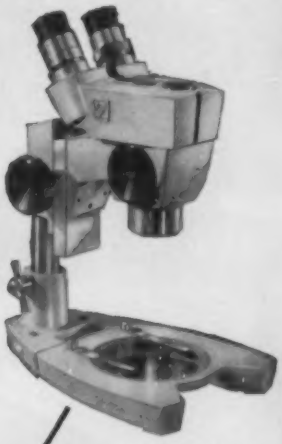

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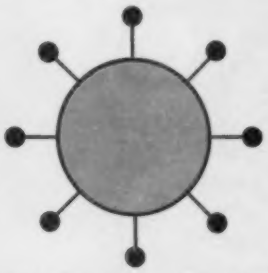
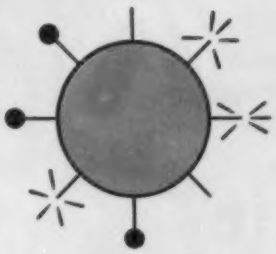
Does the solvent you use "go sour," like this?



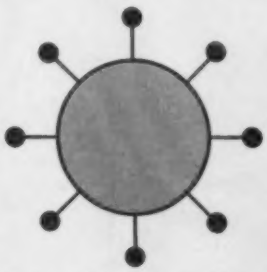
1. The trichlorethylene you use for degreasing metal is protected by a stabilizer (small circles) against heat, light, air, moisture, acids and active metals like aluminum.



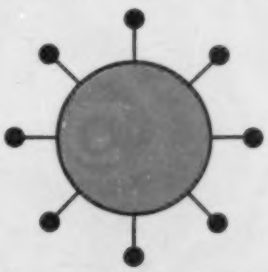
2. Ordinary stabilizers wear out or become depleted during normal use. With some solvents, you have to titrate your bath frequently, and may have to add fresh stabilizer.

3. When stabilizer wears out, your degreaser doesn't function properly. It may even stain metal parts instead of cleaning them. You have to clean out the "sour" bath.

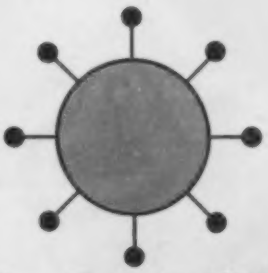
Use Nialk® TRICHLORethylene and get psp ... like this



1. You get full-time protection with NIALK stabilizer's unique action. Notice the difference between the next two diagrams and those above.



2. NIALK stabilizer does not wear out during normal use. It's always there, working. You never have to titrate your bath, or add fresh stabilizer.



3. Even after repeated distillations, you still have complete protection. All the stabilizer is active. Only NIALK has this **psp**—permanent STAYING power.

Why you pay less to degrease with Nialk® TRICHLORethylene

The drawings above demonstrate a difference—a big, cost-cutting difference—between NIALK TRICHLORethylene and conventional vapor-degreasing solvents.

NIALK has **psp**—permanent STAYING power—in its stabilizer. It's neutral, non-alkaline. You never have to replenish it.

psp means cheaper degreasing

You don't have to clean out your degreaser nearly so often with NIALK TRICHLORethylene. You can degrease many more parts between cleanouts.

The NIALK stabilizer actively retards formation of degradation products in your degreaser—cleanouts are easier, faster.

Get proof of Nialk's cheaper, safer degreasing

See for yourself how NIALK with **psp** remains stable, keeps cleaning efficiently long after other solvents have lost their punch. Write on your business letterhead for a resumé of comparative metallurgical tests on five leading brands.

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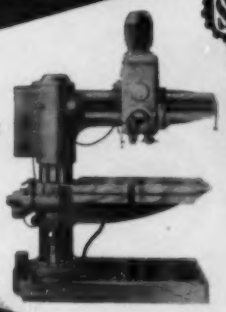

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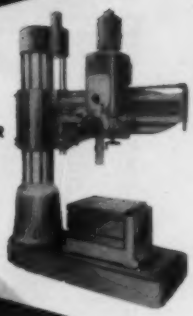
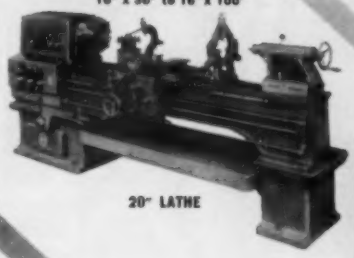


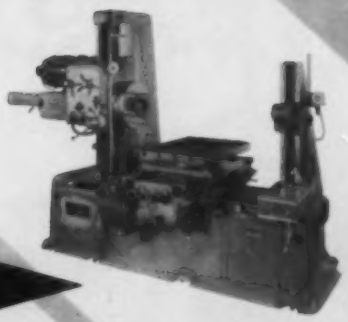
TOOL & ENGINE ROOM LATHES
10" x 30" to 16' x 100'



20" LATHE

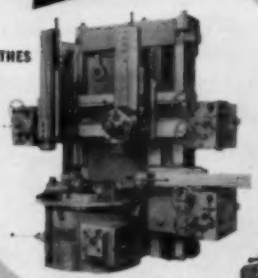
NEW

NEW



OPTICAL HORIZONTAL BORING DRILLING & MILLING MACHINE
Direct Readings in .0001

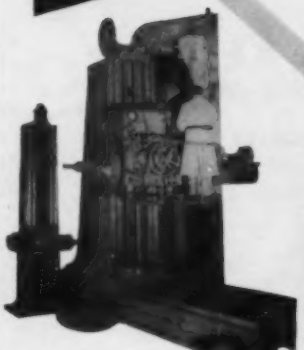
VERTICAL TURRET LATHES
24" to 120"



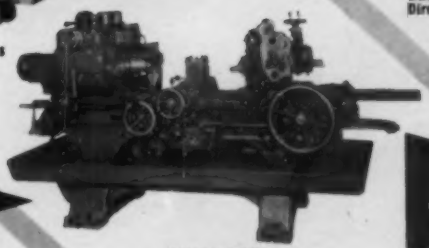
VTL 54" w/3 Heads

NEW

NEW

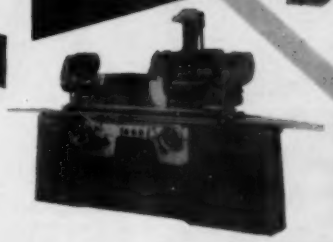


HORIZONTAL BORING MILLS
5" and 6" Spindles



NEW

NEW



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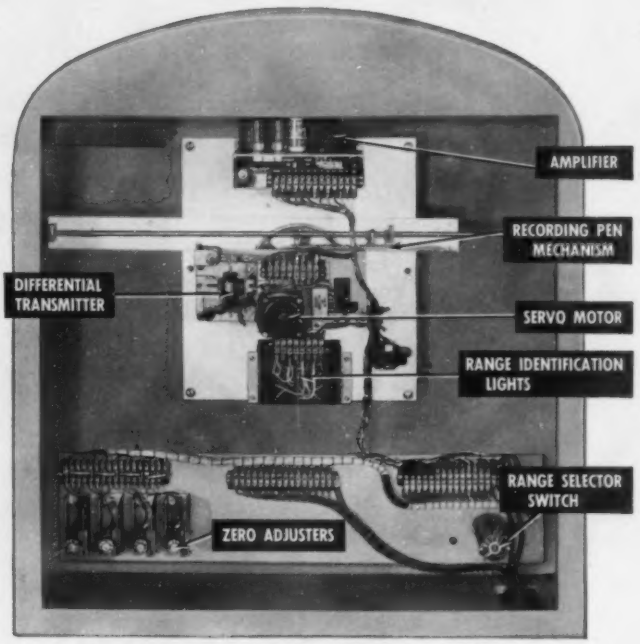

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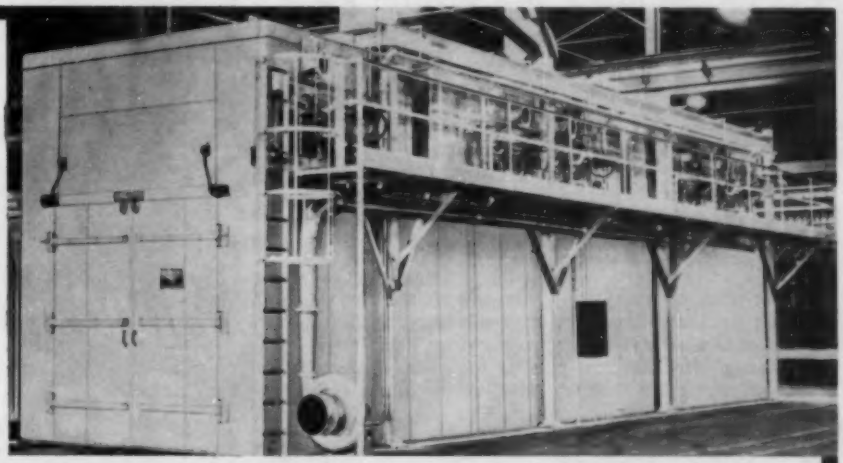
You can't afford inefficient light metal processing



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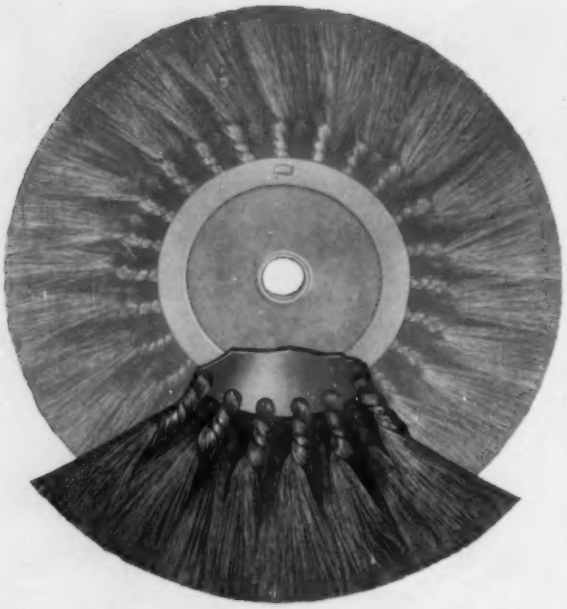

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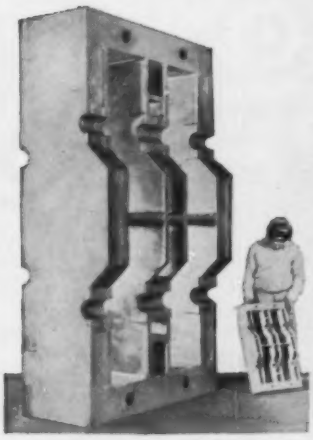

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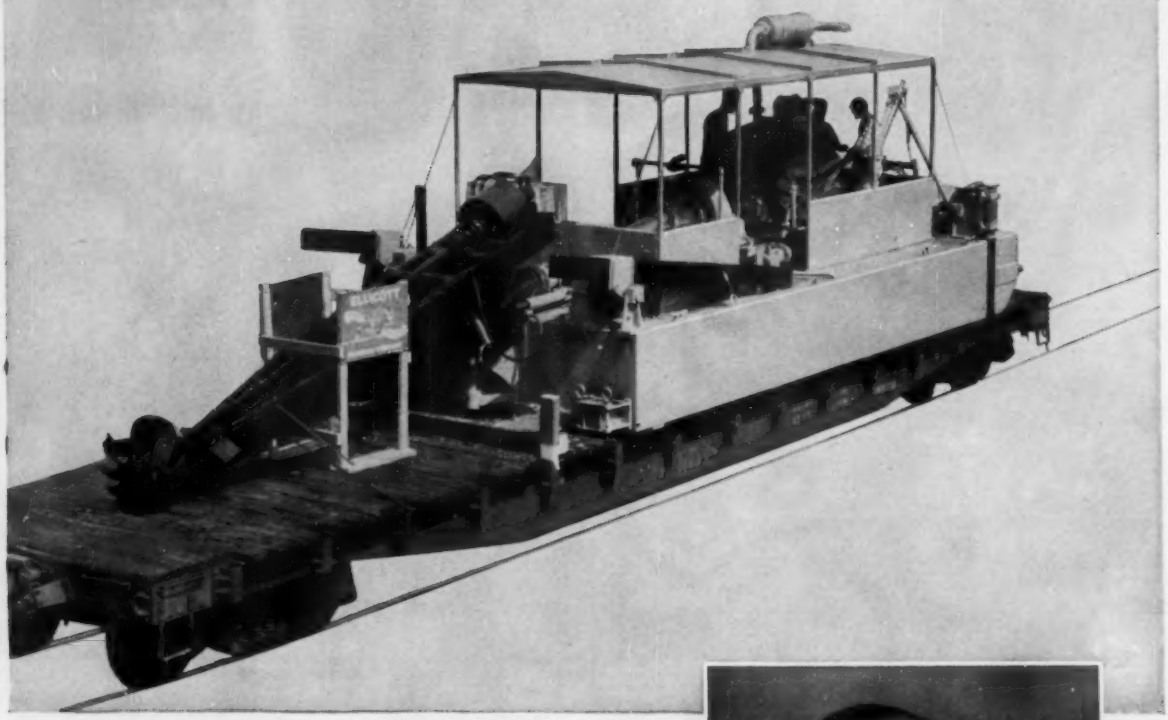

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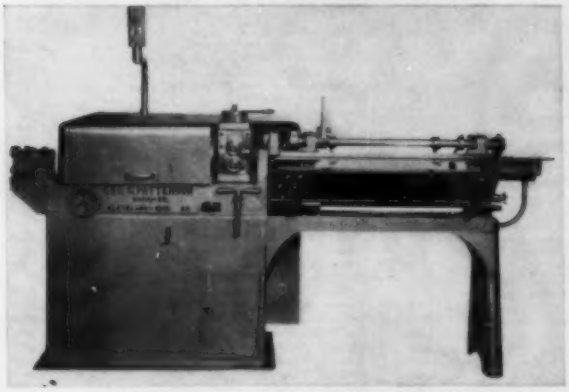

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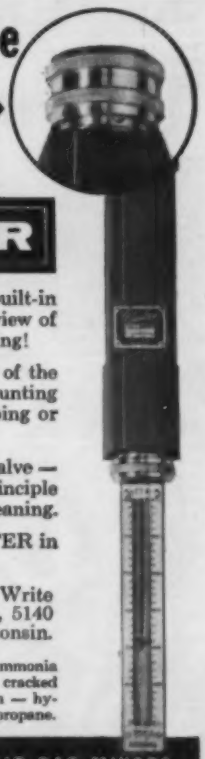

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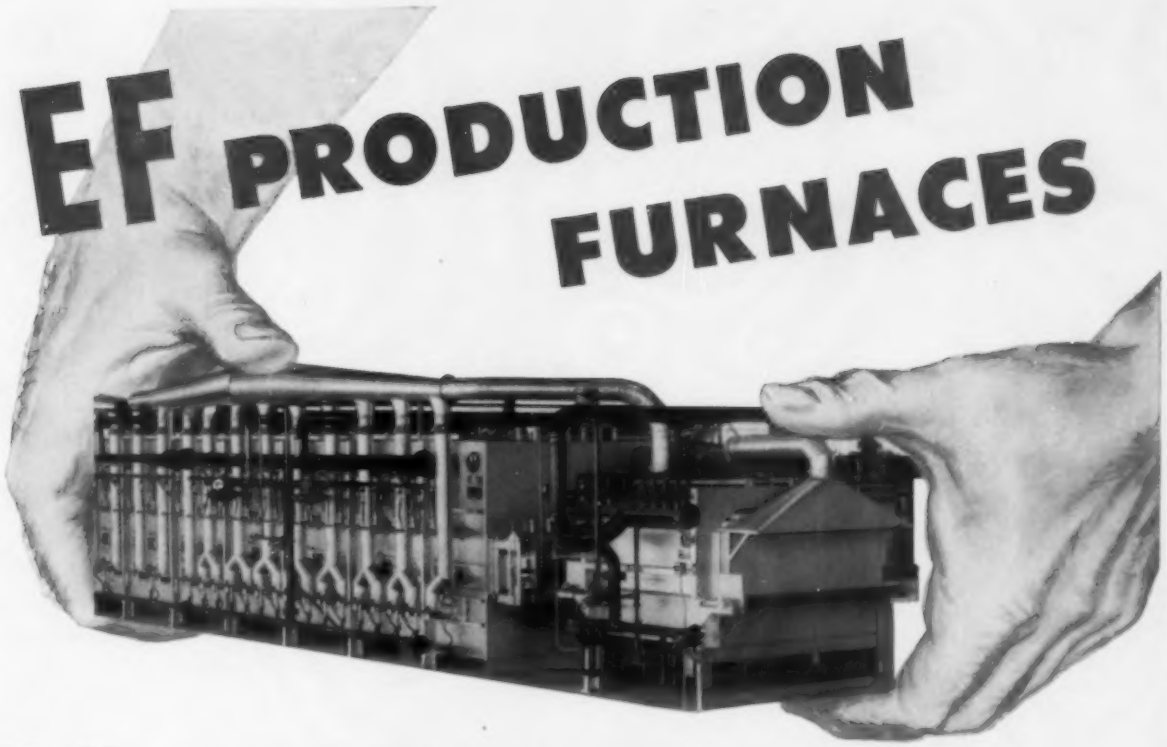

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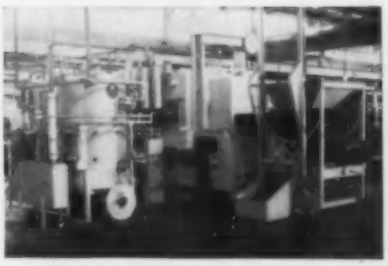

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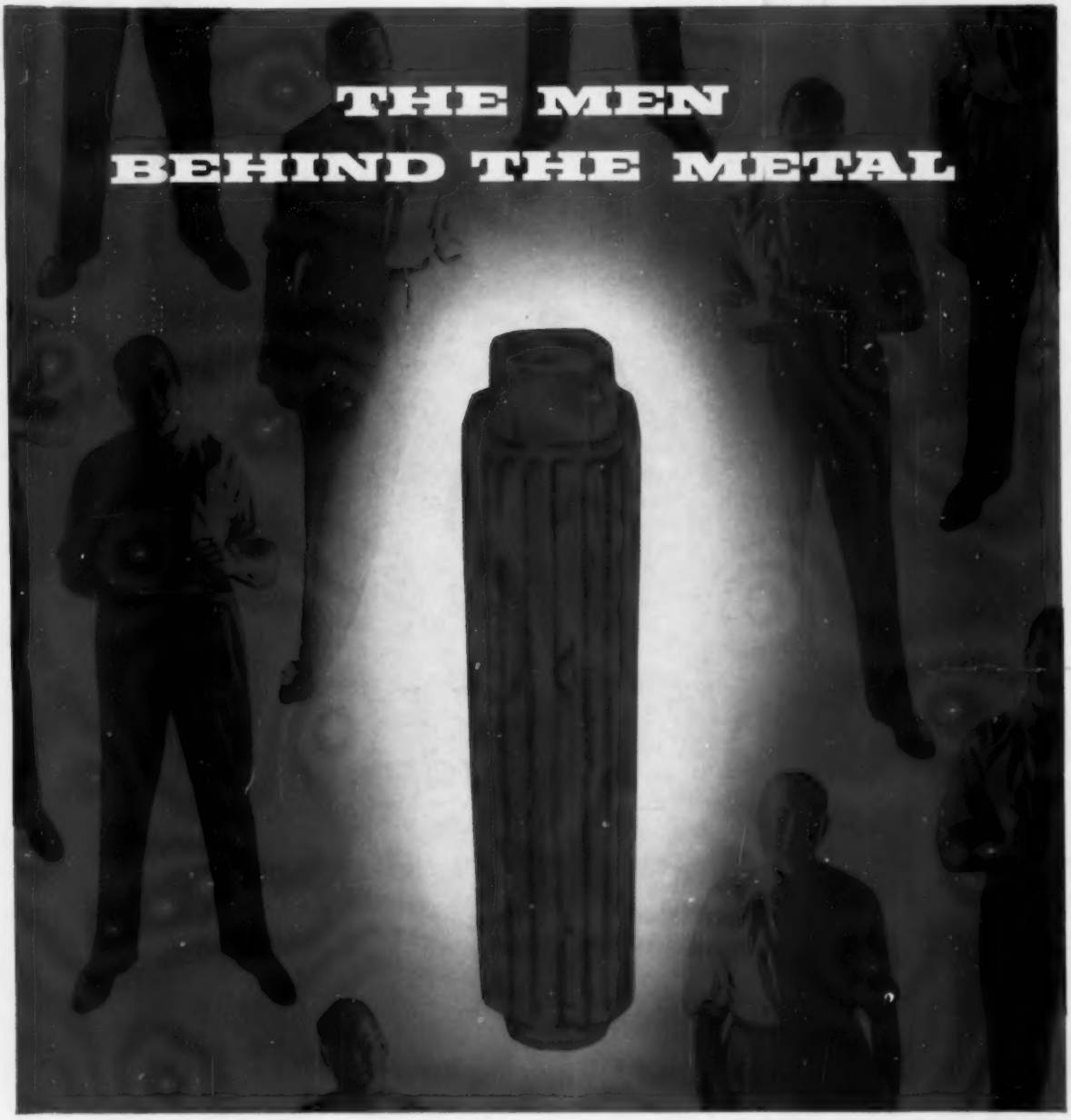

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